

GENERAL ELECTRIC

Review

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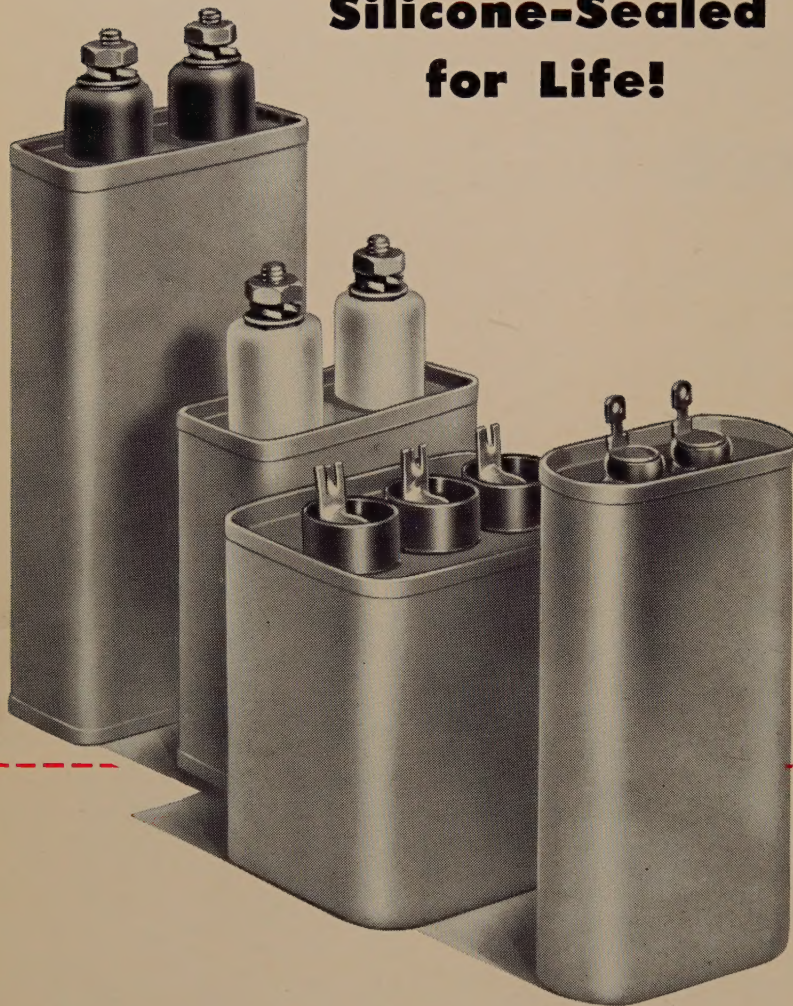


June 1950



CAPACITORS

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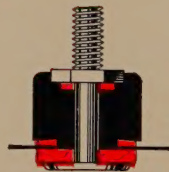
This exclusive G-E feature—with the use of highest grade materials, with strictest quality control and individual testing—make General Electric capacitors finer and more dependable than ever before. *Apparatus Dept., General Electric Company, Schenectady 5, N. Y.*



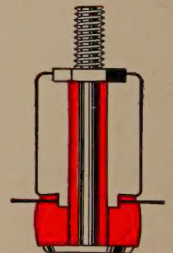
Silicone bushings used with capacitors 660-v a-c, or 1500-v d-c and lower.



Silicone bushings and plastic cups used with capacitors 660-v a-c, or 1500-v d-c and lower.



Silicone gaskets and plastic stand-offs used with capacitors rated 2000-v d-c and lower.



Silicone gaskets and porcelain stand-offs used with capacitors rated 2500-v to 5000-v d-c.

GENERAL ELECTRIC

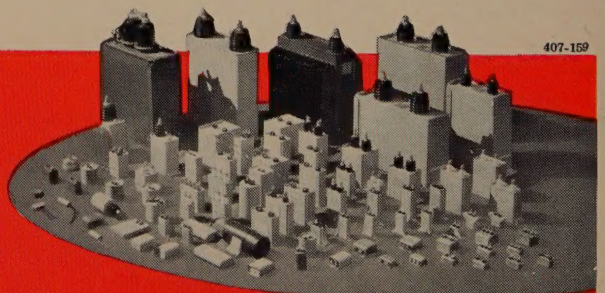
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equipment
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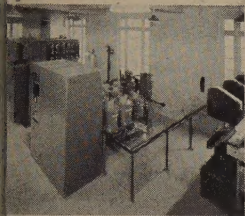


407-159

GENERAL ELECTRIC

Review

JUNE 1950
Vol. 53, No. 6



THE COVER

Rectifier systems have proved to be notably reliable in supplying power for modern transportation equipment. An additional advantage has been found in making the control of the supply systems fully automatic. Substation equipment with automatically controlled mercury-arc rectifiers for conversion of a-c to d-c power for 600-volt railway service, particularly with regard to its operation, control, and protective relaying, is described in the article beginning on page 28.

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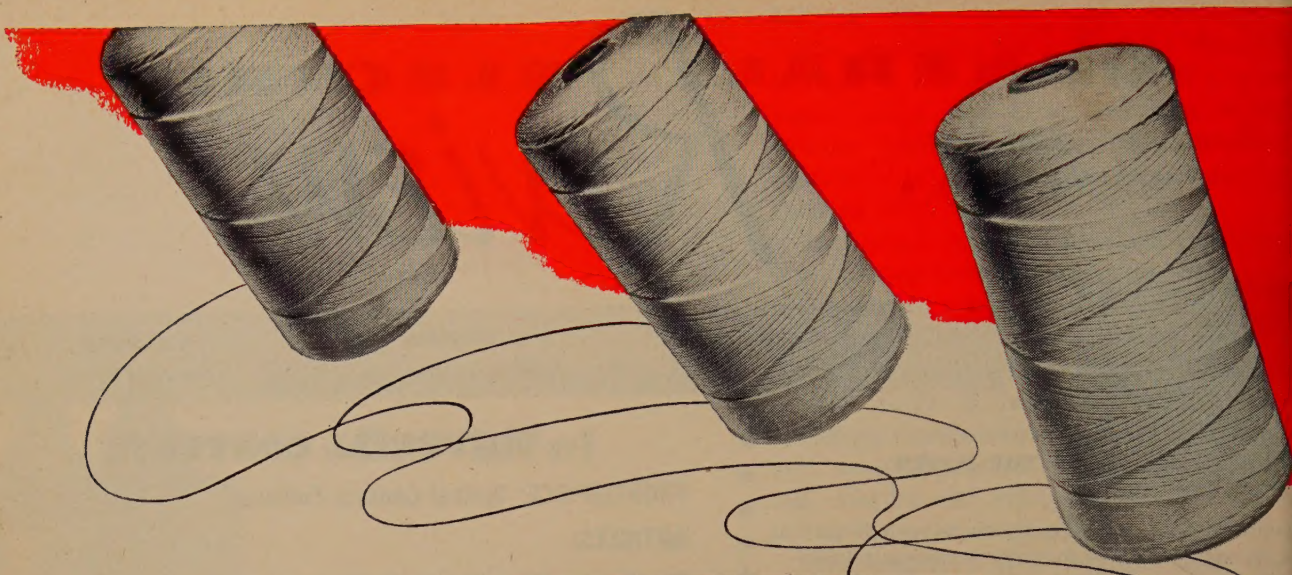
ADVERTISING DEPARTMENT: General Electric Review, Schenectady 5, New York.

CIRCULATION DEPARTMENT: General Electric Review, Schenectady 5, New York.

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Entered as second-class matter, March 26, 1912, at the post office at Schenectady, N. Y., under Act of March 3, 1879. Published monthly by General Electric Company, 1 River Road, Schenectady 5, N. Y. Printed in U. S. A. Copyright 1950 by General Electric Company.



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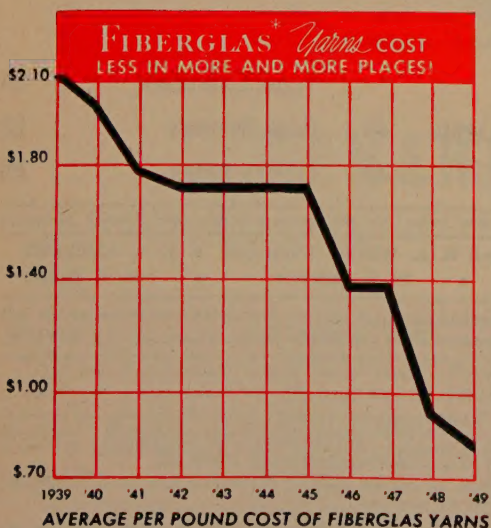
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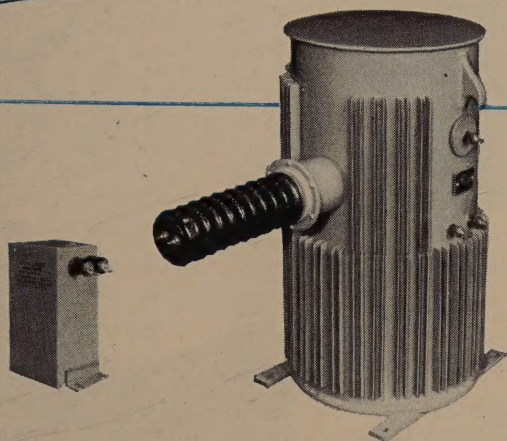
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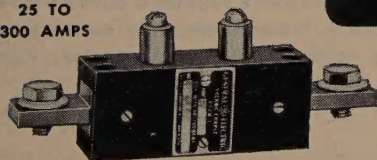
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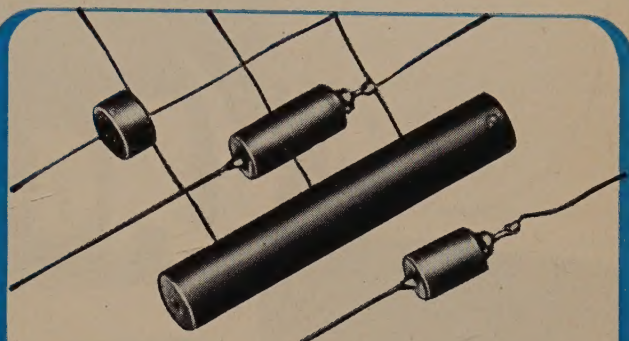


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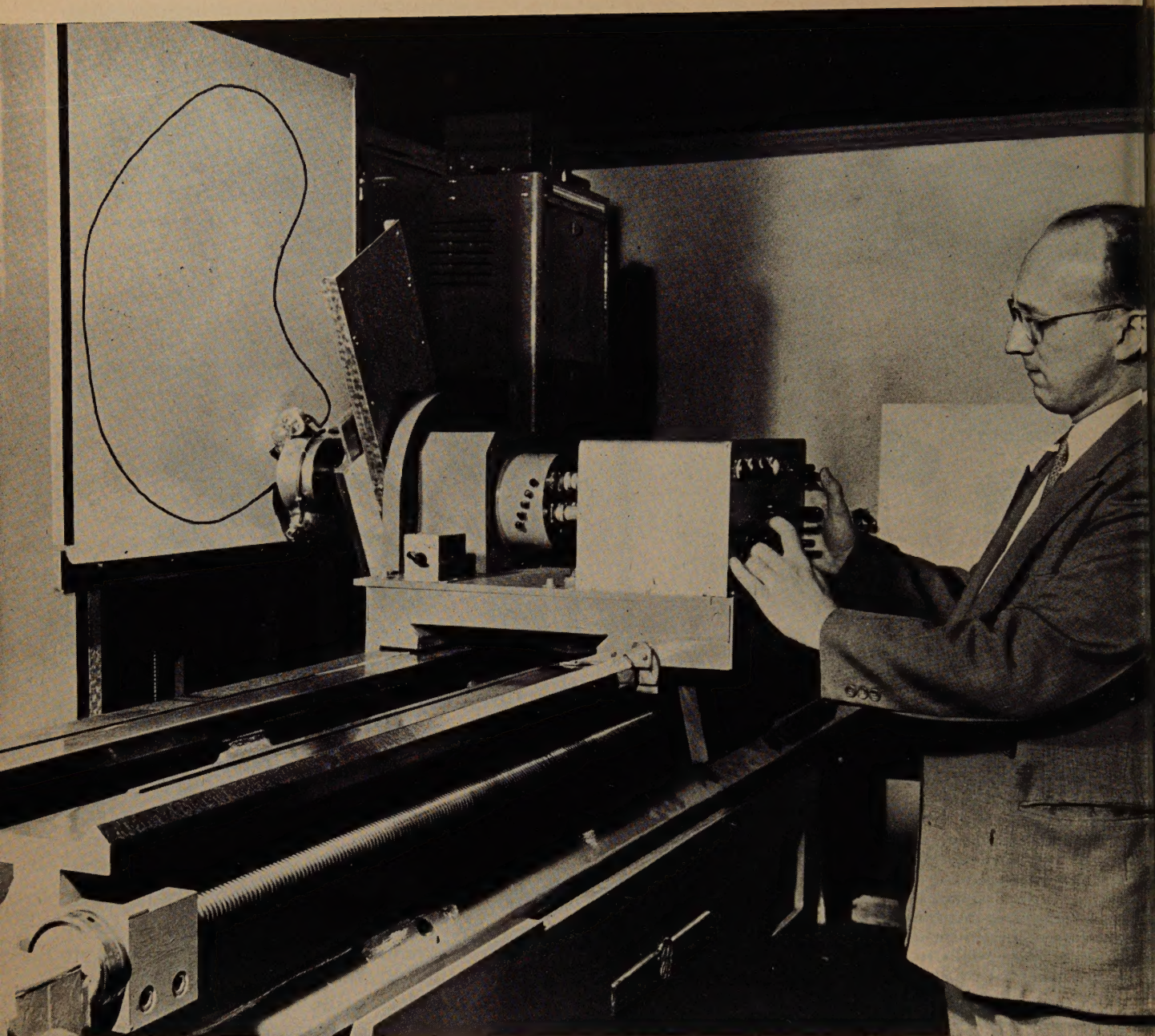
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SOME MORAL ASPECTS OF SCIENTIFIC PROGRESS

By CHARLES E. WILSON
President, General Electric Company



C. E. Wilson

THIS is not an easy assignment for several reasons. Whatever the subject of this lecture may be, in any year and in the hands of any man, it is inconceivable to me that it ever can or should avoid its relationship to the work and the character of Dr. Steinmetz. And yet for me to try to put on the mantle of an engineer or a scientist before this company would be foolish, and in like manner for me to speak of Steinmetz as a human being, in this city, which knew him so intimately, would also be questionable.

The first decision is not hard to make since I have no pretensions to engineering. It has been my lot always to move among engineers through pleasure and compulsion without ever being one. To be able to say, in the great outer world, that one is an engineer from Schenectady, carries with it a standing and respect somewhat akin to the proud statement of another age when a man might say: "I am a citizen of Rome."

The second decision, to forego speaking of Steinmetz as a man, is harder to make. The shadow of his influence and importance seems to grow ever longer with every passing year, just as the recollection by those who knew him of his inquiring mind, his kindliness, his humor, his interest in nature, and his love for human companionship, particularly that of the young and eager, stays fresh. He must have been one of the tallest men measuring four feet, three inches, that the world has known. Abraham Lincoln, whose life ended just a few days after that of Carl August Rudolf Steinmetz began in Breslau in 1865, would clearly have found him a kindred spirit, from his upward-slanted socialism right on down to the pet crows, the raccoons, the alligator, and the monkey named Jenny.

Relatively few workers in the fields of science and technology have publicly concerned themselves with moral issues, or with the moral aspects of their occupation, at least until they attained the age of retirement or the leisure of elder statesmen. That may be for the simplest of reasons—that their schedules were made up of specific activities which left them little time for contemplation. A football player moving down the field behind his blockers does not stop to ask himself

"Why?", nor does a surgeon in the midst of an operation, nor an engineer during the heat run on a turbine.

Yet none of those individuals is operating under a compulsion which he cannot throw off. They have simply made certain major decisions affecting their lives and careers. They have entered a competition where the goals are well-established, the methods are being constantly improved, the rules are understood, and the compass-points are set. In some fashion known best to themselves, they answered that "Why?" when they made their initial decision. In a workmanlike manner they have disposed of the major moral considerations, and what remains is execution of the problem as promptly, as efficiently, and as satisfactorily to themselves as possible. There is nothing reprehensible in this, yet it has undoubtedly led to the conviction, widely held among non-technologists, that an engineer or a research man, for example, is unburdened by either conscience or vision as he goes about his job, that he is not forced to make daily or hourly decisions as to right or wrong, such as must be made by more sensitive operators including poets, politicians, preachers, teachers, lawyers, and business men.

MORAL BASIS OF STEINMETZ' WORK

So far as I know, the moral aspects of Dr. Steinmetz' law of hysteresis loss, or his theory and calculations of alternating-current phenomena, have never been examined from any pulpit or on any radio forum. The young men who visited him at Liberty Hall or at his camp on a tributary of the Mohawk, or who sat before him in the classes of Union College, usually had all they could do to try to understand and absorb what he was saying about specific theories or problems without asking if these things were good or bad for the human race. If they had been forced to any such contemplation, I am sure they could only have answered that they were good, since the results were the increase of knowledge, the acceleration of technological progress toward the universally acknowledged goals, and the continued realization of the benefits of better machines. Yet I submit that the moral basis was always there. It was there in the person of Steinmetz himself, in his relations with people, in his affection for

This article is so paged that, without mutilating other articles, it can be readily removed for filing as a group of full-size consecutive pages.—Editor

simple things and homely virtues, such as his regard for freedom, his feeling for his adopted country, his delight in laughter and good company, and his faith in man's ability to build himself a better and more satisfying world.

In one of his comments he said: "When the age of electricity comes—as it will—electricity will do for everybody all that it can do for anybody. It will do all this in addition to doing a multitude of things of which we have not yet dreamed. I came to America in 1889. It seems a long way back to think where the development of electricity was at that time. It seems a long way ahead to think where it will yet be. For the age of electricity is yet to come. And it will be a great age." This was clearly a consideration of the moral aspects of scientific progress, a relation of a specific activity to a sought-after result.

FRAMING THE ISSUES

We have now come, as many of you are aware, to what is said to be a time of judgment for technology. By the grand accumulation of their activities to date, scientists and engineers suddenly find themselves performing upon a world stage with a very wide proscenium arch, before an audience that no longer resembles a professional meeting or colloquium, but which includes in its vast and critical throng the teachers and preachers, the lawyers and politicians, the statesmen and philosophers, and the common people. In many respects it is a frightened audience, but a fascinated one. To the degree that it is frightened, or perhaps just uneasy over its future safety, it is inclined to be critical. It has a tendency to mutter and indulge in some heckling from the upper balconies. It wants to blame somebody for the critical state of the world, and it is looking squarely at technology. If the devices and the weapons that engineers and scientists have made possible, through the pursuit and application of new knowledge, are going to be turned against this audience to wipe it out, or to reduce it to a cringing and mutilated shambles, then the engineers and scientists are going to be blamed. If these same devices and weapons are to be put into play to save our skins—and thereby to devastate some other group, of course—then the engineers and scientists are going to be heroes again, for a day or a generation or so. I do not think these are the right answers because they are so inconclusive. They beg the question. The issues are not being properly framed and, until they are, the proper answers will not be forthcoming.

To state this matter in its very simplest and harshest terms, a good many of your fellow citizens are afraid of the atomic bomb and the proposed hydrogen bomb. They are afraid of the possibilities of biological warfare. They are properly afraid of any weapon so sweeping in its possible effects that it has the power to wipe out our civilization and reduce us to another unhappy

cosmological accident. From their fear they move with faulty but excusable logic to the conclusion that the men who make such weapons possible are the villains of the piece, and that the most charitable view to take is that they have finally outsmarted themselves by planting the seeds of universal destruction.

SCIENCE AND TECHNOLOGY

Being neither a scientist nor a card-carrying philosopher, I have nothing but the temerity of the amateur observer and a reasonable amount of faith in my fellow men to qualify me to make and complete the remainder of this argument, but I shall attempt it because I think the cause is worthwhile. You will have to make certain allowances for my non-professional terminology and methods as we proceed. Perhaps I should say at the outset that I am aware that I am employing such terms as *science* and *technology* rather loosely; but for our purpose that does not matter too much. Fundamental science differs from technology in many respects, of course—in motivation, in methods, and certainly in the way in which it is economically supported. Technology is the useful application of scientific progress, and having practical ends it pays its way, whereas historically pure science has had to be subsidized in some manner. When he considers the atomic bomb, the average person does not distinguish too clearly between these branches, and he lumps together pure research men at one end and engineers at the other.

Actually this has aggravated the misunderstanding of which we speak. Dr. Henry D. Smyth, of the Atomic Energy Commission, pointed out recently that for a long time technology was a relatively simple matter, and could go along on its mechanical knowledge without having to know much about physics and chemistry, but that this situation began to change with the advent of the electrical industry, when technological advances began to depend more and more upon the co-operative labors of men rigorously trained in scientific fundamentals. The two great wars rapidly closed the gap, with chemists and physicists going directly from their laboratories into such fields as gas warfare, sound ranging, and electronics. At the end, there was only a dramatic six years between the discovery of nuclear fission and the explosion of the atomic bomb.

Here are two things among many that have happened to put technology on the spot in the eyes of the common man. First, scientists have begun to inject themselves into political and economic arguments, sometimes with more enthusiasm than judgment. They did not use to worry much about freedom of speech because it was taken for granted and was outside the framework of their day-by-day activity. Now they recognize its importance to their professional interests, and they speak out, which automatically makes them fair game in any argument. Second, modern scientific research has become enormously expensive and must be sup-

ported by tremendous sums coming directly or indirectly from taxpayer-citizens. So long as the layman has to put up the cash, he is going to try to have a voice in the way it is spent—and yet in the field of atomic energy it is necessarily being spent according to plans and decisions which the layman is many times incompetent to judge.

The result of all this is that scientists and engineers are being labeled as the architects of destruction by poorly informed and frightened men who nevertheless feel that they have paid their admission and have a right to speak. It seems to me that we have two chores to perform: first, we must point out the fallacy in such thinking; second, we must try to come up with some of the true moral aspects of scientific progress which will have an important bearing on our destiny as free men.

Does science concern itself with moral persuasion or with moral judgments? Does it concern itself with faith, or with courage? On the other hand, does technology teach materialism, or the survival of the fittest, or the purpose of creation, or the efficacy of the supremacy of the state as opposed to the rights of the individual? Are the men of science fatalistic? The answer to all of these questions must be in the negative.

"Science," says one of its eloquent disciples, "does not teach anything at all beyond its boundaries, and those boundaries are severely limited by science itself. Science merely observes what is apparent to man's senses, describes what it sees, condenses this description into generalized form for convenient use, and thus predicts how material things will function in their interrelationships."

Thus does Vannevar Bush proceed to explode the fallacy of the guilt of technology, and he proceeds with these words which I believe further dramatize the issue:

"So those who contend that mankind is engaged merely in a futile dance, a meaningless fluttering over the cruel surface of the earth before an inexorable curtain descends, with no more to life than a struggle for a seamy existence, do *not* do so on the teachings of science. They do so because they conclude that the limited observation of our weak senses and their petty aids encompasses all there is of reality. From such a fallacy come materialism and the new fatalism now built into a political system geared for conquest."

Fatalism is as old as philosophy, I suspect, and most of us who think about it at all think of it as a negation or a denial of the human spirit, of human ambition and vision. We think of it as a timorous submitting to forces that, if they are not beyond our powers of resistance, are at least beyond our powers of understanding and our willingness to resist. It is lying down before the storm and the fire. It is, as this audience will be quick to say, everything that Dr. Steinmetz was not. If he had been a fatalist, he would have let himself be turned back at Castle Garden when he sought admittance to the United States. In fact, he would

never have gotten that far, because he would never have resisted the political tyrannies of Bismarck and fled his native land.

But now, if Bush's point is well made, and it seems to be, fatalism is become more than a negation and has been turned into an active philosophy based on the interpretation of science as utter realism. That I believe we must resist.

Science is facts, not a philosophy. Science is a test tube, a telescope, an x-ray tube, and a hydrogen bomb. It is a series of calculations and equations. It is a set of tools. Science is a record of what we know, just as engineering is a record of what we have done with that knowledge. But science does not draw conclusions as to what is right or wrong, what is best for a man or a nation or a race. Men are the ones who do these things, and they may be men of good will and faith and courage, or they may be men of evil intent, hungry for power, anxious to preserve themselves at all cost. There is nothing moral or religious or hostile or inspirational in science unless man puts it there, and when he does he is operating not as a scientist or an engineer but simply as a human being playing at being a soldier or a politician or a priest.

ARRANGING THE FACTS

As soon as we begin to arrange the facts of science into a previously conceived man-made pattern, we begin to get some surprising and ironical results, but the fault is with the pattern and with our arranging, not with the facts themselves or the men who demonstrated and proved them. For example, take the subject of how long a man lives, about which a Yale professor was writing the other day. It is popularly supposed that our lives are being gradually lengthened by successful war on disease. It is a demonstrable fact that the mathematical average of man's allotted years has improved, and your insurance company will tell you so, but this is largely as a result of a concerted attack by the medical profession on infant and childhood diseases. The total living that individuals can pack into their lives remains about constant, however, and it seems that we are being saved—statistically—from measles only to die of cancer and heart disease. Man starts out in life with a high death rate, said this professor, like that of an oyster or a mackerel; in middle age his chances of survival are better; but in old age he suddenly expires in droves, like a starved fruit fly. All in all, the human survivorship curve most closely resembles that of the bighorn sheep of Mt. McKinley. This is a perfectly sober specimen of the fantastic patterns that can be woven from scientific facts if the weaver has a will to do so.

Scientific progress is a fact—not a scientific fact, however, and to be honest it is probably only a valid conclusion which we can draw at this stage of civilization. Nevertheless let us say it is a fact, in view of the evidence there is all around us. Let us put a bold period after that fact, while we consider some of its moral

aspects. We have a common obligation to expose the fallacy of the guilt of technology, but that alone is not enough, because it is purely an act of defense in an age that calls for a planned offense.

A DISTURBING ASPECT

Here is one aspect of our progress which is disturbing. For 300 years science has thrived because of the free interchange of information between men in various countries who were working in similar fields. This free interchange has now all but disappeared, and as a result of our voluntary action. A great deal of water has gone under the bridge across the Mohawk since that day more than a quarter century ago when a number of distinguished Russian scientific dignitaries, in silk hats and formal clothes, called upon Steinmetz and found him working in his canoe, clad in the customary bathing suit. It was a not unusual example of co-operation which ignored international boundaries and, in the process, demonstrated that such co-operation moved the knowledge of the whole group forward.

The laboratories of Europe and Asia were once open to us, as ours were to them. The curtailment of free communication has been brought about, in a sense, by necessity, and in another sense, by our very progress itself. It is not good, even though it is presently inevitable. We will do well to keep that fact in mind.

A related aspect has already been suggested, because it has moral implications, and it concerns our atomic-energy program and the present decision to devote our resources and talents to the development of a hydrogen bomb, at tremendous financial cost in terms of money, scientific personnel, and atomic materials. Concentration on this project must necessarily mean the deferring or perhaps the abandonment of other nuclear-energy projects, not to mention scientific and technological projects of other kinds.

The plain citizens of the United States, and their descendants, must pay the price in dollars, in deferred benefits of which they may not now have any knowledge, and perhaps with their lives and property. At least one authority, the former Chief of the Theoretical Physics Division at Los Alamos, has concluded that the H-bomb could well make our country more vulnerable, instead of less secure, since there are not more than 20 cities in the world, he says, that would justify the dropping of an explosive of such wasteful striking force—and half of those targets lie within this country. I don't suppose it is any secret that you are sitting pretty close to one of them at this moment.

Please do not construe these remarks to be any expression of opinion on my part as to whether the policy our government had adopted is correct. My point is simply that this is a tremendous decision for anyone to have to make, with vast moral implications, because it may well affect the lives and fortunes of so many common citizens who are not competent to express themselves in the matter, but who must nevertheless pay the piper. Also, I cannot forego pointing out, at this point, that this decision is not a decision

made by men acting as scientists or engineers, but by men acting as national leaders.

IMPORTANCE OF SCIENTIFIC FREEDOM

Here is still another moral aspect of scientific progress—the vital importance of scientific freedom, and within our own borders this time, not in terms of exchanging information with other nations. Again it is a problem that grows out of science, and which must ultimately be solved by us as people, not by the technologists themselves. Referring to Dr. Smyth, of the Atomic Energy Commission, again it is his inescapable conclusion that a free society is necessary to creative science. He points out that the Nazi regime did not last long enough to demonstrate completely the effects of such a regime on science and technology in general, but that Germany's failure to develop an atomic bomb was undoubtedly influenced by party politics, limitation of criticism, exaggerated national conceit, and racial intolerance, to the point of strangulation of technical effort.

The Soviet regime, Dr. Smyth continues, has shown us so far only that it is possible with determined effort and a good spy system to obtain a particular device already proved workable by others, and he thinks it will be interesting to see how far the Russians will get in their attempts to apply theories of genetics based on party fanaticism rather than on scientific evidence. He poses the dilemma best in his own words as follows:

"How much talk should be permitted? Everyone is agreed that the technological details of atomic bombs and other weapons should be kept secret; everyone is agreed that the public should be informed on technical matters that affect public policy; everyone is agreed that we must continue to teach students the principles of science without restriction and that scientific research and publication are fine things that should be fostered generally. Everyone agrees that freedom of speech is something we should fight to defend—and everyone agrees that the sixty thousand employees of the Atomic Energy Commission and its contractors should not have complete freedom of speech."

THE MORAL RESPONSIBILITY

In posing these few moral aspects of our progress in science it has been my purpose to call attention first of all to the fact that the body of scientific achievement is an entity in itself, and that there is not attributable to it any responsibility for the uses that may be made of it in a world split down the middle between those who believe fatalistically in a supreme conquering state, and those who believe in the freedom and dignity of man. Let those who are afraid of the future throw into the lists a little courage and a little more militant activity to insure that future. Let them appreciate more the fact that they are free to draw conclusions and implement the decisions freely arrived at in a democratic society, rather than lie down before the storm or mutter in the gallery. In fact it is they, and not the technologists as such, who have the domi-

ant obligation to help shape policy with the tools that a beneficent science has provided for us.

Secondarily, I believe it is important for scientists and engineers to do more than just stand by to be explained and defended. As citizens they share in this common obligation to pick up the tools, and use them to help shape their destiny. In fact, it has always been my own conviction that scientists and engineers have a little more of an obligation in this respect than the average man, because they are members of a professional estate with somewhat higher responsibilities. They represent one of the finest, most cohesive, best rewarded, and most sensitive strata of American life. They are truly charged, not just to build America and promote it technologically, but to preserve it as a dynamic community of free men, conscious of leadership and the sacred obligations of leadership.

CONCLUSIONS

We have said that science does not concern itself with faith. But the men of science, like all men, must not deny faith as a vital force, because faith is the sun which brings meaning and splendor to their achievements. We have said that science limits its own boundaries severely, but the men of science may aspire to any heights. There is nothing in the book that says that their reach should not exceed their grasp. It must do that in the days ahead, if we are not to deny our birthright, if we are going to preclaim, with Steinmetz, that "it will be a great age."

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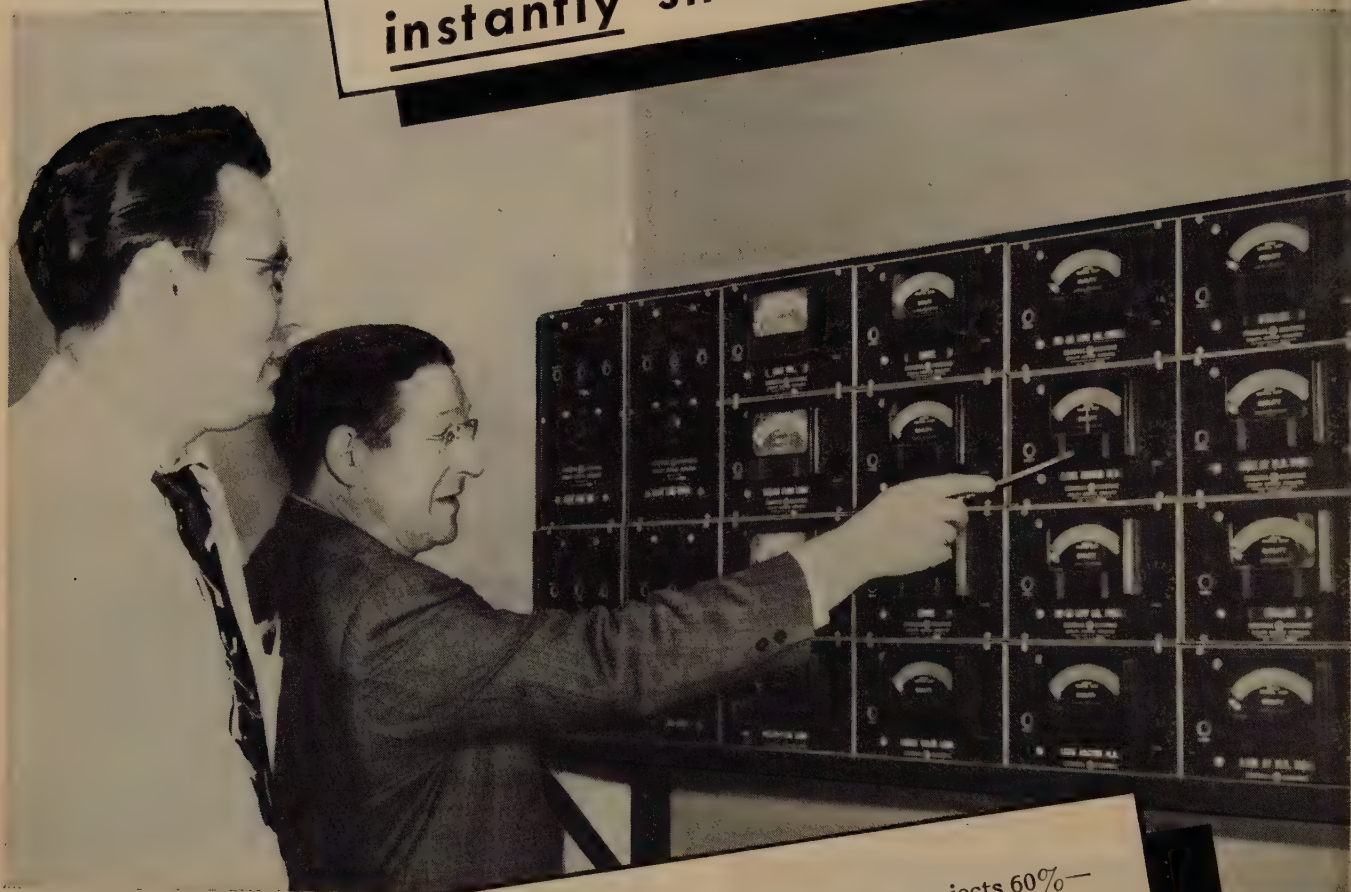
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PRACTICAL ENGINEERING

USES OF PROBABILITY PAPER . . . Part I

Variable data can be analyzed conveniently by simple plots on probability paper. A straight line through two key points, and conformity to the normal law, answers many related questions

By A. BOYAJIAN

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General Electric Company, Pittsfield, Mass.



VARIABLE data are frequently susceptible of profitable analysis very conveniently with the aid of the "probability paper" used in plotting the basic graphs presented in FIGS. 1 and 2. The method is explained most simply with an example.

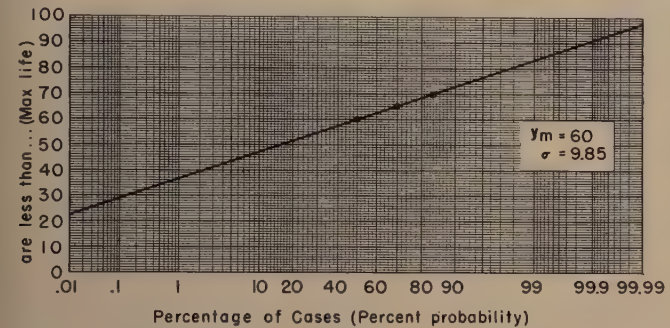


Fig. 1. Straight-line plot on probability paper gives ready answers to questions for specific cases. This line, pertaining to the data given in Table I, is determined by plotting two key points ($x=50$, $y=60$) and ($x=84$, $y=69.9$)

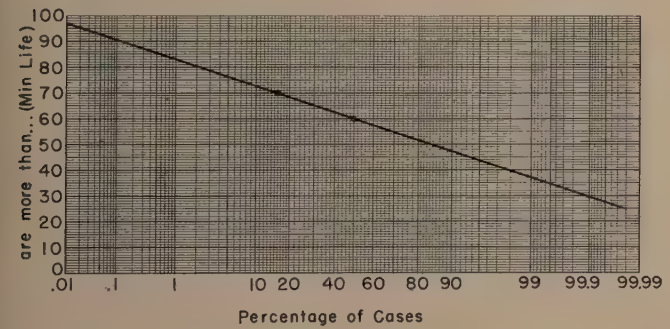


Fig. 2. Alternative plot for the data given in Table I. This line utilizes the points ($x=50$, $y=60$) and ($x=100-84$, $y=69.9$) to give answers in terms of "more than the average value"

TABLE I
BASIC DATA

Sample No.	y (life)
1	47 units of time
2	55
3	60
4	65
5	73
Mean value $60 = y_m$	

PROBLEM

In a life test, five samples of a product have behaved as given in Table I.

We wish to know reasonable answers to the following questions:

- (1). What is the life expectancy of a random unit in the lot?
- (2). How certain is the answer to Question (1)?
- (3). What are the chances of the breakdown of a random sample in (a) less than 30 units of time; (b) in not less than 95 units of time?
- (4). If risks of premature failure are to be held down to 1 percent, what should be the life rating of a unit?
- (5). If the cost per premature failure (cost of complaint) is given, how could we decide on a guaranteed life for the product?
- (6). The more data we have from the life tests, the more confidence we would have in our conclusions. How can this be evaluated quantitatively?
- (7). The product is low priced, and inspection of each unit is out of the question. How many samples would you test from each lot to O.K. it for shipment?
- (8). How would you compare the quality of successive batches for uniformity of product? (This is the problem of quality control in manufacturing.)
- (9). The X-axis scale of the probability paper is nonuniform and is ruled according to the so-called "normal" law of probability. Inasmuch as there are many other possible laws of probability, how can we get an indication whether or not the normal law applies to our product, to justify (or discredit) the use of this special paper for our purpose?
- (10). If the normal law does not seem to apply to our product, can any reasonably useful inferences or suspicions be entertained?

Many of these questions (and others related to them) can be answered by drawing a straight line through certain two points on this paper; and with slightly more work, the other questions can be answered.

This article is so paged that, without mutilating other articles, it can be readily removed for filing as a group of full-size consecutive pages.—EDITOR

TABLE II
CALCULATION OF σ

(1) Original data (from Table I)	(2) Deviations of the individual y 's from their <i>mean</i> value y_m which is 60 (from Table I)	(3) Square of Column (2). (All squares are positive.)
y	$y - y_m$	$(y - y_m)^2$
47	-13	169
55	-5	25
60	0	0
65	5	25
73	13	169
Sum of Column (3) 388		
Divided by $(n-1)*$ 97		
Square root 9.85 = σ		

*Here, instead of n , the number $(n-1)$ is used, because only $(n-1)$ of the entries in the third column are independent. This would be more obvious if the deviations were reckoned from one of the readings, for in that case the deviation of that reading from itself would always be zero, not a variable. The number of independent variables is no different when reckoning the deviations from the mean of all readings. Perfectionists have other corrections to apply to the standard deviation of very small samples, but such refinements are beyond the scope of this article.

It will be seen that the scale along the X-axis of probability paper is not uniform, and that 0 is at infinity on the left, and 100 at infinity on the right. If one needs consolation for this, he might be reminded that 0 is at infinity on the left on a slide rule too, though the scales are not alike.

DRAWING THE STRAIGHT LINE

The first point needed is based on the *mean* value y_m of the five samples ($=60$) and is plotted against $x=50$ on the probability paper (FIG. 1). By *mean* value we mean the algebraic sum of the data divided by their number n .

The second point is based on a quantity called the *standard deviation* of the data and represented by sigma (σ) calculated as shown in Table II, from which it will be clear that σ is the root-mean-square value of the deviations of the individual data from the mean value of the set. Thus σ is an index of the degree of scattering of the data, above and below their mean value.

From Table II, σ is 9.85. Then the second point for our straight line is $(y_m + \sigma) = 69.9$, to be plotted against $x=84$ (FIG. 1). This figure, 84, comes from the normal law of probability. For the present we must take it on faith and commit it to memory.

TABLE III
LIFE EXPECTATION OF A RANDOM SAMPLE

Entry No.	Life Span	Probability Percent
1	60 $\pm$ 6.7	75 - 25 = 50
2	60 $\pm$ 5	70 - 30 = 40
3	60 $\pm$ 4	64 - 32 = 32
4	60 $\pm$ 3	60 - 36 = 24
5	60 $\pm$ 2	58 - 42 = 16
6	60 $\pm$ 1	53 - 47 = 6
7	60 $\pm$ 0.5	52 - 48 = 4
8	60 $\pm$ 0	50 - 50 = 0

Drawing a straight line through these two points in FIG. 1, we will be in a position to answer most of the listed questions.

To clarify the meaning of the graph, it will be noted that the abscissa are titled alternatively as "Percentage of cases" and "Probability," and the ordinates are titled "are less than...". Taking $x=50$, y is seen to be 60; and the title implies that 50 percent of the cases are less than 60 (the mean value), or that the probability of an observation being less than 60 is 50 percent.

For all practical intents and purposes, "*percentage frequency of occurrence*" (*actual or potential*) of a *specified observation* and "*the probability*" of that observation are synonymous terms.

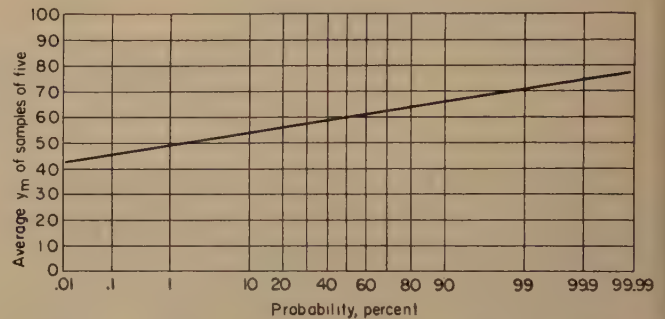


Fig. 3. Straight-line plot as used to test the reliability of conclusions derived from statistical data

Instead of the "less than" specification in the ordinate, we might have drawn our straight line to represent "more than," by plotting the second point ($y=69.9$) not against $x=84$ but against $100-84=16$ (FIG. 2), and it would have served all our purposes just as well.

Questions (1) and (2)

- (1) What is the life expectancy of a random unit in the lot?
- (2) How certain is the answer to Question (1)?

Answers

It does not seem to need any knowledge of probability theory to see that the expected life of a random sample must be the average, y_m , equal to 60. What does "expected" life mean? Presumably it means that, on further tests, if sample after sample should test 60, we would say, "Well, that is what it means." And this turns out to be definitely wrong! Let us consult the graph.

The graph (FIG. 1) says that 50 percent of the samples should test below 60, which implies that 50 percent will be above. This is very different from samples prevalingly testing 60, because the graph further says that 30 percent should test below 55 and 70 percent below 65 (or 30 percent above 65), so that on the whole only 40 percent should test between 55 and 65. That is, the probability of a sample testing 60 ± 5 is 40 percent. Let us tabulate (Table III) a few such calculations from the graph.

From Entry No. 8 in Table III, the probability of a life span of exactly 60 is nil, and the probability of being 60 to nearest integer (that is, 60 ± 0.5), is only

4 percent. As we widen the tolerance, the probability increases. The most logical answers to both questions (1) and (2) are contained in Entry No. 1: *The life expectancy of a random sample is 60 ± 6.7 , and its probability is only 50 percent.* The chances of the life span of a random sample falling within or outside of this zone is 50 percent. The formula for this is $(y_m \pm 0.67\sigma)^{(1)}$, and is worth committing to memory, because it can also be used as an alternative for the second point of our straight line, plotting $(y_m + 0.67\sigma)$ against $x = 75$, instead of $(y_m + \sigma)$ against $x = 84$. It may be recognized now that 84 is the probability of an observation being less than $(y_m + \sigma)$.

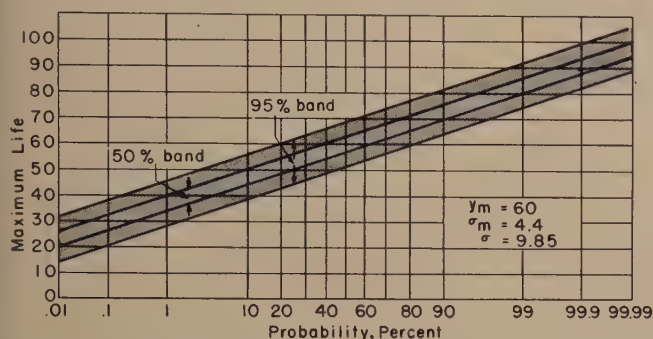


Fig. 4. Probability bands formed by straight-line plots give definite indication of justified degrees of probability

Question (3)

What are the chances of the breakdown of a random sample in (a) less than 30 units of time; (b) not less than 95 units of time?

Answer

In FIG. 1, we find (a) the probability of failure in less than 30 units of time is a little over 0.1 percent; and (b) the probability of failure in not less than 95 units of time is $100 - 99.975 = 0.025$ percent.

Question (4)

If risks of premature failure are to be held down to 1 per cent, what should be the life rating of a unit?

Answer

The graph plotted in FIG. 1 shows that, to hold premature failures to 1 percent, the life rating should be 37 units of time.

Question (5)

If the cost per premature failure (cost of complaint) is given, how could we decide on a guaranteed life for the product?

Answer

This problem involves other questions besides those answerable by our data. For instance, a higher life guarantee has a sales appeal with a certain advertising-dollar value, but it involves a greater complaint expense. Our graph helps only to evaluate the latter risk. The cost of a complaint multiplied by the probability of the complaint yields the expected complaint expense.

⁽¹⁾ The coefficient 0.67 is the abbreviation of 0.6745, . . . , not of 0.666 . . . but the resemblance to the latter may be helpful in remembering it.

So, if the advertising value of a higher life rating can be evaluated, a rational decision can be reached.

Question (6)

The more data we have from tests, the more confidence we would have in our conclusions. How can this be evaluated?

Answer

This question amounts to asking how reliable are y_m and σ when these are obtained from a limited number of observations. The answer is that these have sigmas of their own, and their variability is calculated as follows.

(a). According to the normal law, if σ is the variability of the individual members of the total product, then the variability of the mean value of a group of n units will be

$$\sigma_m = \sigma / \sqrt{n} \quad (1)$$

In the present case, with a group of five samples, the best (and only) estimate of σ is 9.85, and therefore our estimate of σ_m will be $9.85 / \sqrt{5} = 4.4$.

If the true mean value of the total product is y'_m , and the mean of our sample is 60, then

$$60 \text{ will be within } (y'_m \pm k\sigma_m) = (y'_m \pm 4.4k) \quad (2)$$

k depending on the degree of probability desired. Solving Equation (2) for y'_m ,

$$y'_m = 60 \pm 4.4k. \quad (3)$$

FIG. 3 gives the probable distribution of the mean values of samples of five with a standard deviation $\sigma_m = 4.4$. It may be verified from this curve that y_m falls within 60 ± 3 with a probability of 50 percent, and 60 ± 8.8 with a probability of 95 percent.

It follows from this that the value of y_m that we plotted in FIG. 1 as 60 (against $x = 50$) is uncertain and that the graph, instead of being a line (as in FIG. 1), is really a band (as in FIG. 4) with a tapering boundary like a shadow band, the width to be assigned to the band depending on the degree of probability desired. FIG. 4 shows the 50 percent and the 95 percent probability band widths for the present case, corresponding to $(60 \pm 0.67\sigma_m)$ and $(60 \pm 2\sigma_m)$. The higher the probability desired, the wider is the band.

To illustrate the use of FIG. 4 to answer the question, "What is the probability of a sample failing in less than 50 units of time?" the answers from the two bands are as given in Table IV.

TABLE IV

Answer	Probability of the correctness of the answer
From the wide band: Between 3% and 46%	95%
From the narrow band: Between 9% and 24%	50%

If the bands in FIG. 4 appear too wide and uncertain, judged by eyes used to graphs that are single lines, it only goes to show that one must not expect a great deal of certainty from only five observations, especially when they differ from each other as widely as in Table I.

(b). To answer the question about the degree of reliability of σ , if the true standard deviation of the individual members of a complete group to which the normal law applies be designated σ' , then the sigma of a sample of n units will be variable from sample to sample by the index σ_σ :

$$\sigma_\sigma = \sigma' / \sqrt{2n} \tag{4}$$

With this value of σ_σ , we may plot a probability curve for the sigmas of such samples, to determine the probability of various degrees of variation in them.

This uncertainty in sigma indicates a further uncertainty in the bands in FIG. 4. However, as sigma is a correction to the mean value in FIG. 4, and σ_σ is a correction to the correction, this second-order correction need not worry us too much in engineering calculations.

A practical use of σ_σ will be indicated in the answer to Question (8), later.

Question (7)

The product is low priced; inspection of each unit is out of the question. How many samples would you test to O.K. each lot?

Answer

This question, as to how large a sample to test, involves a decision on how far it is desired to narrow down the band shown in FIG 4. From Equation (1), σ_m , and therefore the band width (vertically), is inversely proportional to $\sqrt{n}$. So if, instead of 5 tests, we had 20 tests, the band width in FIG. 4 would have been only one half as wide, and with 125 readings, only one fifth as wide.⁽²⁾

Considering an exhibit like Table IV, one can suit his degree of conservatism to reduce the spread in the first column by increasing the data.

Question (8)

How would you compare the quality of successive batches for uniformity of product? (This is the problem of quality control.)

Answer

Let us see how a factory foreman might apply the foregoing principles to his product. He evaluates y_m

TABLE V
DISTRIBUTION OF DATA

(1) Percentage of Cases	(2) Are Below	(3) Are Above
20	47.1	72.9
40	55.1	64.9
60	60.1	59.9
80	65.1	54.9
100	73.1	46.9

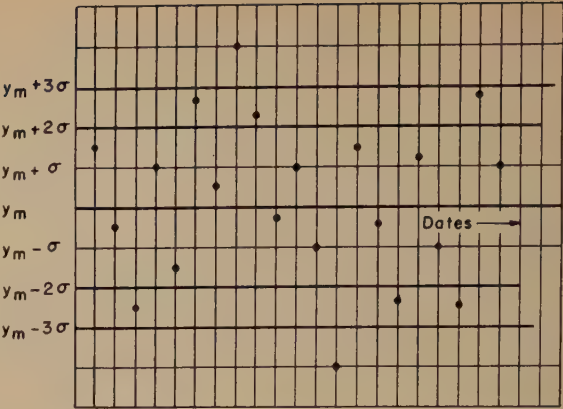


Fig. 5. Graphical records of variability show regions corresponding to degrees of deviation

and σ for data, going as far back as 6 months, and plots them as shown in FIG. 5. The abscissas are days, and the ordinates the value of y for the day—one point plotted for each day. He observes that the great bulk of the data falls inside the band $y_m + 2\sigma$; a small fraction between $(y_m + 2\sigma)$ and $(y_m + 3\sigma)$; and another small fraction between $(y_m - 2\sigma)$ and $(y_m - 3\sigma)$; and a few still farther away from the mean. He reasons that, while anything that is possible may happen, large deviations (whether + or -) are apt to happen more frequently as the result of assignable specific causes operating in

TABLE VI
REVISED INTERPRETATION OF DATA

Sample	
No. 1	10% below 47
(20%)	10% above 47
No. 2	10% below 55
(20%)	10% above 55
No. 3	10% below 60
(20%)	10% above 60
No. 4	10% below 65
(20%)	10% above 65
No. 5	10% below 73
(20%)	10% above 73

addition to those that bring about the normal-law distribution. Because there can be no critical dividing line, he may feel that a deviation greater than $\pm 3\sigma$, representing only 0.13 percent probability, must be considered suspicious. So he draws two "control" lines, $y_m + 3\sigma$ and $y_m - 3\sigma$, with the thought that in the future any product falling outside those lines should be investigated for an assignable cause for its deviation, frequently comparing the circumstances of similar (low or high) points for common factors. As more and more of the disturbing causes are discovered and eliminated, the quality (that is, the correspondence to y_m) will become better and the variability lower.

⁽²⁾Theoretically, 125 readings will be scattered a little worse than 5 readings and will therefore yield a little larger σ , so that the band width will not be quite as narrow as one fifth.

That is the philosophy of quality control.⁽³⁾

A control chart similar to the foregoing can be set up also for the standard deviations themselves, with $(\sigma + 3\sigma_s)$ as the upper limit and $(\sigma - 3\sigma_s)$ as the lower; any group whose sigma falls outside these limits is then subjected to an investigation.⁽³⁾

Question (9)

How can we get an indication whether the normal law applies to our product, to justify (or discredit) use of probability paper?

Answer

To check whether the normal law applies to our product (Table I), we must plot our data and see if they fall on the straight line plotted in FIG. 1. The method of doing this involves a little uncertainty; that is why we did not begin this article with it.

TABLE VII					
REVISED DISTRIBUTION OF DATA BASED ON TABLE VI					
	Below 47	Below 55	Below 60	Below 65	Below 73
Percentage of Cases	10%	30%	50%	70%	90%
	Above 47	Above 55	Above 60	Above 65	Above 73
Percentage of Cases	90%	70%	50%	30%	10%

Each observation in Table I represents one fifth of the data, and therefore considering Sample No. 1, one might say (dipping into one more significant figure) that 20 percent of the cases are below 47.1. Considering the first and second samples together, he might say that 40 percent are below 55.1, etc., as listed in Table V, Column 2. Following the same principle, one could tabulate in reverse sequence, upward, and would then get the third column in Table V. A comparison of the second and third columns will show that they are inconsistent. For instance, the second column says 20 percent of the cases are below 47.1. If so, then 80 percent ought to be above 47.1; but the third column says that 80 percent are above 54.9. If one should say that what is above 54.9 is also above 47.1 and therefore

(3)For detailed instructions see, (a) *Control Chart Method of Controlling Quality During Production*, a bulletin issued by the American Standards Association; or, (b) the *A.S.T.M. Manual on Presentation of Data, Including . . . Control Chart Method of Analysis . . .*; or, (c) *Quality Control Charts*, a bulletin issued by the British Standards Institution.

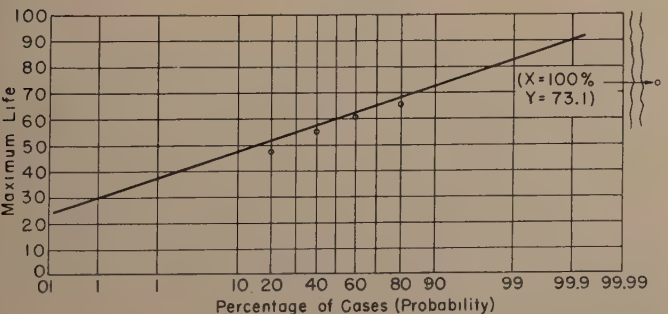


Fig. 6. Lack of correspondence of plotted points with straight-line plots for a given set of conditions is an indication of faulty method or incorrect interpretation of data

not inconsistent, and go ahead and plot Columns (1) and (2) on the same sheet with our straight line, he would produce FIG. 6. Along most of the range, the agreement is not as good as one might have wished, and the last point shown on the chart is really infinitely far away from the graph. We may well suspect the method of compiling Table V as faulty, and look for a better principle of reckoning of the distribution of data.

In our data (Table I), certainly, twenty percent of the cases read the same value, 47, because they consisted of only one case! If the twenty percent had consisted of several cases, their average could still have been 47, but some of them (say, half) would have been less than 47, and the others more. Therefore, we split our samples, and say that, according to the first sample, 20 percent, 10 percent were below 47, and 10 percent above 47. Doing the same with each sample, Table VI results.

By inspection of this table it is seen that the distributions of the total data will be those shown in Table VII.

In this table, the "above" and "below" percentages are consistent as to their boundary values and also add up to 100 percent in every case.

Plotting the "below" values along with the previously determined straight line (FIG. 1), we get FIG. 7—and the points fall almost perfectly on the straight line. Especially, that impossible end point in FIG. 6 now falls nicely into the groove.

The common sense of the foregoing method may perhaps be made still clearer by plotting the data of Table I as a column diagram, without cumulating them (FIG. 8). If the column diagram is to be represented by a smooth curve, the upper dashed curve, joining the left-hand corners of the columns, would not be acceptable, as it includes more area than the columns. Neither would the lower dashed curve, joining the right-hand corners, be acceptable, as it leaves out some of the area belonging to the columns. The solid curve, joining the midpoints of the columns, would make a much better approximation. This places half of a column below the observed value and half above, as advocated previously.

The excellent agreement of the data with the straight line in FIG. 7 may be accounted for more by foresight than luck, because the data were originally chosen

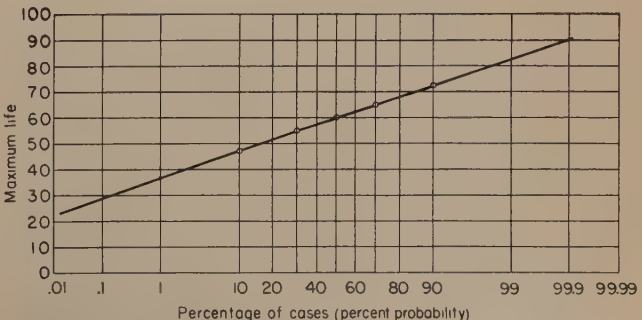


Fig. 7. Reinterpreting data gives a more tenable arrangement of "above" and "below" values, substantiated by good agreement with the straight line

according to the normal law! The data had to be chosen so in order to prove that, not the data, but the method used in Table V and FIG. 6 is faulty. So let us consider now data not taken from tables.

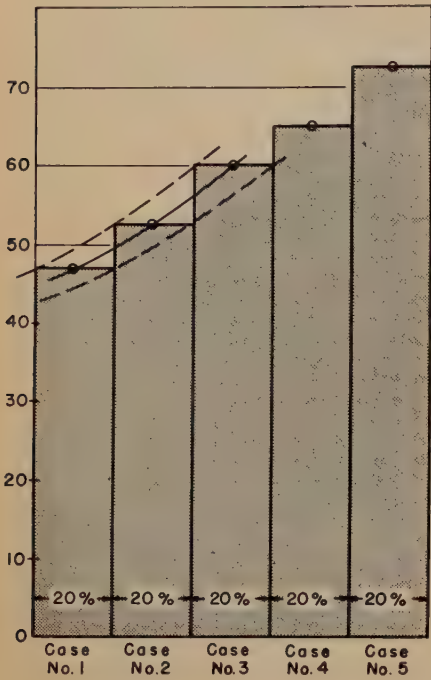


Fig. 8. Column diagram representing the data given in Table I

Another Example

In an example given by K. A. Brownlee,⁽⁴⁾ there were three shifts in a factory, with the following accident records:

Shift	Number of Accidents
A	1
B	7
C	7

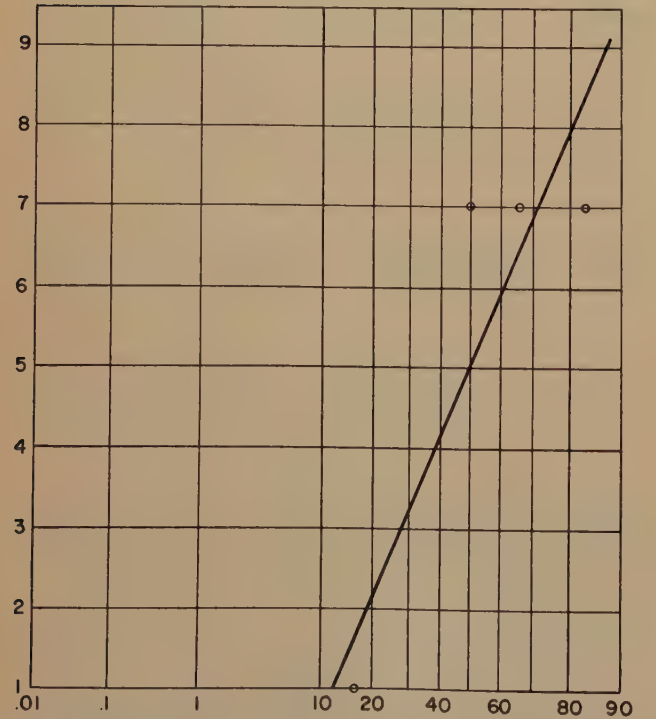


Fig. 9. Straight-line graph and plot of individual points of data from an accident record

The question is: are the differences significant? Brownlee tackles this by another method somewhat more advanced than ours and arrives at the conclusion that the data do not justify the conclusion that the differences are significant. He notes that "this result will probably be surprising to the nonstatistician, who almost certainly would have assumed that it was quite certain that the three shifts did differ," but continues to stand by his mathematics as against nonmathematical common sense. Let us see what conclusion we would arrive at by our elementary methods.

The y_m —mean value—of the data is 5; the σ , 3.46. They are represented by the straight line of FIG. 9. The probability of a low value like 1 accident or less is seen to be about 10 percent and therefore need not arouse suspicion of a significant difference between shifts, *provided* that the normal law applies. So let us check this point by plotting the individual data. Interpreted as in Table VI, the data take this form:

Shift A	{ 16.7% of cases	under 1
33.3%	{ 16.7% of cases	above 1
Shift B	{ 16.7% of cases	under 7
33.3%	{ 16.7% of cases	above 7
Shift C	{ 16.7% of cases	under 7
33.3%	{ 16.7% of cases	above 7

The proper method to cumulate these data is going to be a problem, but one possible way is as follows: 16.7 percent of the cases are under 1; 50 percent under 7; 83.3 percent under 7; 33.3 percent above 7 (or 66.6 percent under 7). Plotting these values in FIG. 9, we note that the points are badly out of line. This leads us to suspect that the three shifts are *not* alike within the normal law, just as unsophisticated common sense would have concluded.

The fact that the lower limit is zero and one of the data has the first possible value next to it (that is, 1 accident) makes the bottom portion of the curve unreliable too. That brings up another matter that might as well be considered here.

Laboratory data generally plot well except at the end points. This peculiarity is of frequent occurrence and the philosophy underlying it is worth understanding.

(a). The normal law is to the probability field what the sine wave is to alternating currents—an ideal—neither law completely realized in practice but very convenient and generally approximated well enough within the accuracy standards of slide-rule calculations. One cannot count too much on engineering phenomena to follow the normal law closely into probabilities (or improbabilities) less than 1 percent or above 99 percent. For instance, the normal law assumes that the variable can assume (though with low probability) negative values as well as positive; frequently this is impossible, and therefore the end-point data will diverge from a straight line.

⁽⁴⁾K. A. Brownlee: *Industrial Experimentation*, Chemical Publishing Co., Brooklyn (1947), p. 37.

(b). The factors bringing about variability in a product may be divided into two classes: first, those that follow either the normal law or some other smooth law; and, second, those that are erratic. In those results in which the normal law operates with a very high probability, the erratic factors will naturally be less conspicuous; but where the normal-law factors operate with a very low probability, the erratic factors can be very conspicuous. As erratic factors can never be ruled out in practice, low probabilities calculated by the normal law cannot be relied on too much.

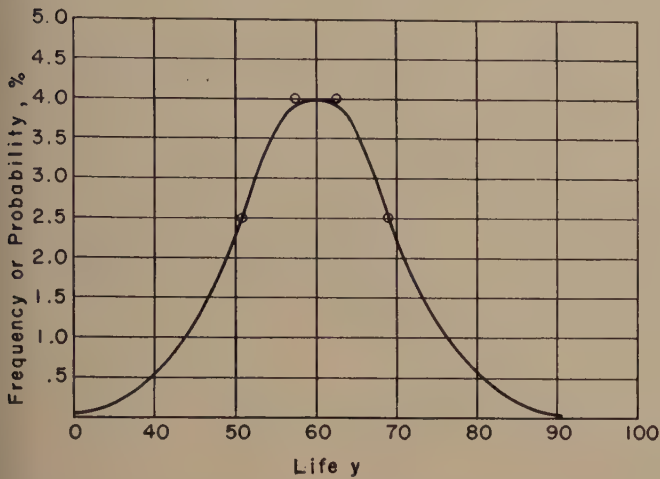


Fig. 10. A percentage-wise plot of statistical data. On ordinary graph paper, this is the familiar configuration of the probability curve

Question (10)

If the normal law does not seem to apply to our product, can any reasonably useful inferences or suspicions be entertained?

Answer

The normal law may be inapplicable (or appear so) in a given case for a variety of reasons. Assignable causes leading to erratic results have already been noted under the answers to Questions (8) and (9). Another reason may be that the variable cannot deviate beyond certain limits—cannot become negative, for instance.

Other possibilities are: the variable may be unsymmetrical or “skewed” on the two sides of its mean value, as would be the case if the variable has a definite limit on one side and not on the other, or it has definite limits on both sides but not equidistant from the mean value.

In other cases the variable may be subject to two sets of forces, each one of which produces a normal-law distribution but around different mean values.

In still other cases, the force (law) which makes the greater deviations from the mean value more and more difficult, and therefore unlikely, may follow a formula different form that of the normal law.

Analysis of these types is helped by plotting graphs of another kind. The kind we have been working with in this article is called more completely the “probability-integral” curve, because in it the data are cumulated

for plotting, as we plotted the percentage numbers of all below 30 . . . , all below 40 . . . , etc. Another way of plotting the data would have been by narrow groups, like the percentage between 39.5 and 40.5, the percentage between 40.5 and 41.5, etc. A typical plot of this latter kind by the normal law is a bell-shaped curve on uniformly ruled paper (Fig. 10), which we might call the *original* probability curve, meaning the curve *before* integration. The integral curve is used most generally not only because it answers most of our practical questions more directly, but it also has a strong tendency to yield a smooth curve when the data are not precisely in accord with the normal law. In contrast with that, data plotted in the style of the bell-shaped curve tend to be jagged and thus expose, in an exaggerated manner, any deviations from the ideal curve. Hence the bell curve is more useful for the study of the nature of the law which a given set of data may seem to follow. It may be remarked, however, that scanty data are capable of being interpreted and plotted differently, thus causing uncertainty.

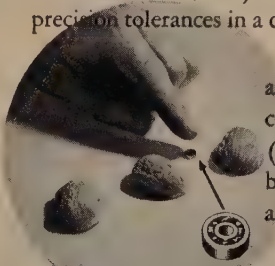
The possibilities of extending the method is illustrated in the following problem. Suppose that Table I and Fig. 1 apply truly to human mortality up to 100 years. A person is just past 65. What is the probability of his reaching 80? (Answer in footnote.⁽⁶⁾)

⁽⁶⁾ Answer: $(100 - 97.5) / (100 - 70) = 8.3\%$. Explanation: the population past 65 is $100 - 70 = 30$ percent. The population past 80 is $(100 - 97.5)$. Hence the ratio of the number of favorable cases to the total cases is as indicated in the solution.

(To be continued)

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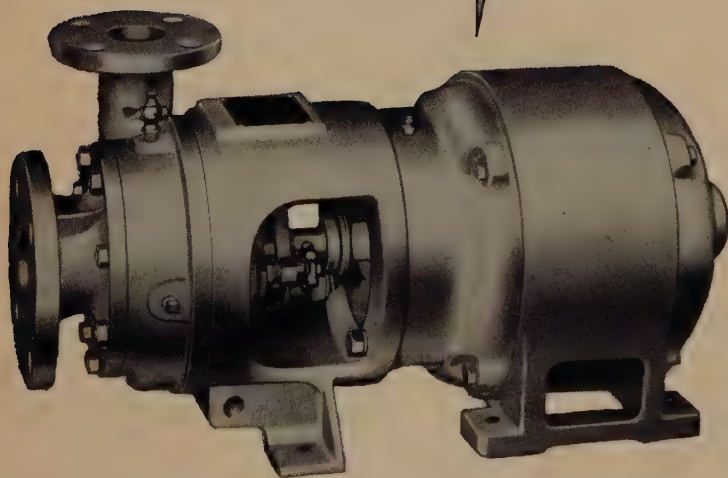
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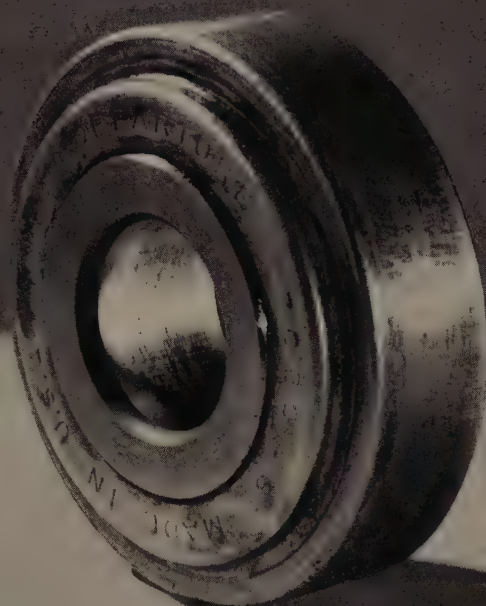
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OVERLOAD PROTECTION OF MOTORS ON DELTA-WYE SUPPLY

Reasons why, in most installations, only two thermal elements in the control are sufficient. Types of exceptions to be considered

By D. B. CARSON

Industrial Engineering Divisions, Apparatus Department
General Electric Company



D. B. Carson

IF THE power supply from a three-phase primary distribution system is reduced to single-phase, by the opening of one primary-line conductor, any motors which are energized from wye-delta (floating neutral) or delta-wye transformer banks connected to this system may be exposed to overcurrent conditions that may not be properly detected by the two thermal overload relays normally installed in motor control equipment.

The single-phase condition produces a current unbalance in which one line current may be higher than either of the other two line currents. If the high current exists in the line which has no thermal element in it, the motor may not be given proper overcurrent protection by the control. FIG. 1 shows the values of

current and voltage existing when a stalled motor is connected to a delta-wye transformer bank energized from a three-phase system in which one leg has been opened.

In the evolution of low-voltage (600-volt or less) industrial power systems, it is now becoming apparent that much is to be gained by grounding the system neutral. This is usually done by using system supply transformers connected delta primary, wye secondary, with secondary neutral grounded. Table I summarizes these advantages and provides a comparison between the grounded and ungrounded methods of operation.

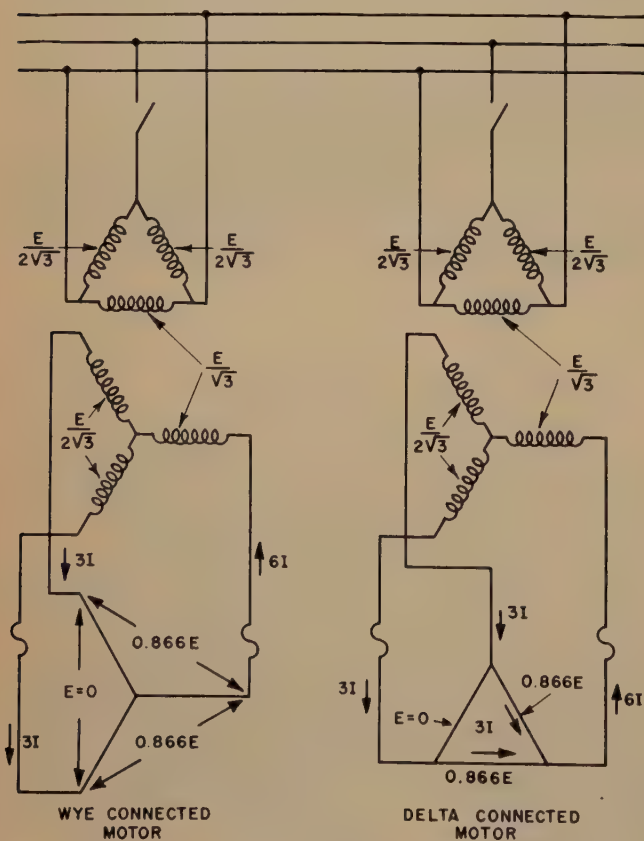


Fig. 1. Locked rotor currents in wye-connected and delta-connected motors supplied from delta-wye connected transformers operating on single-phase primary voltage. (The transformation ratio represented here is 1:1)

E = motor rated voltage

I = 3-phase full load current

Three-phase locked rotor current = 600%

This article is so paged that, without mutilating other articles, it can be readily removed for filing as a group of full-size consecutive pages.—EDITOR

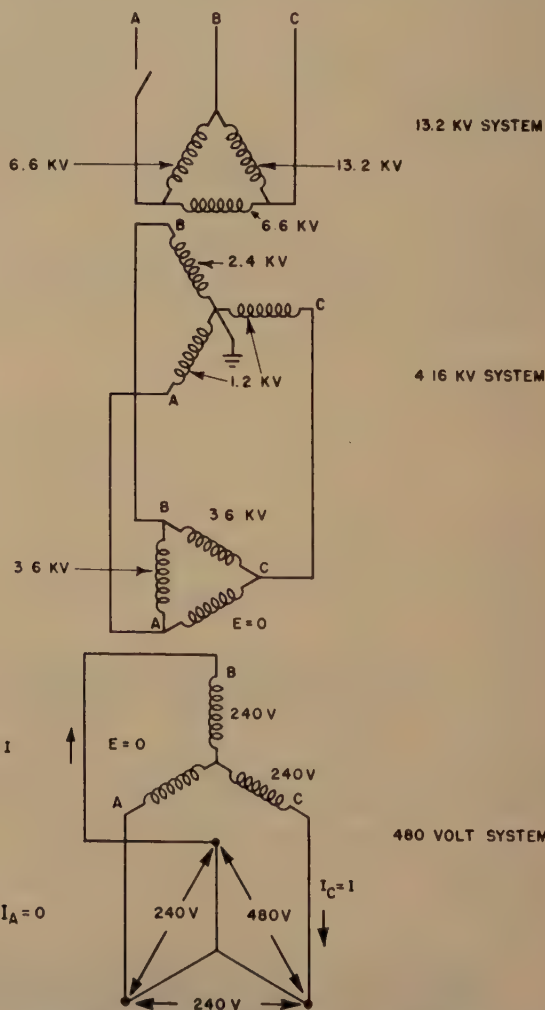


Fig. 2. Locked rotor currents in three-phase motor supplied from double delta-wye connected transformation operating on single-phase primary voltage

Neutral grounding generally involves the use of delta-wye load-center unit substations. With that type of power supply, how serious is the problem of providing adequate motor overload protection against the possibility of current unbalance under primary single-phase conditions?

Over 95 percent of the load-center unit substations installed are protected by three-phase power circuit breakers, thus single-phasing is possible only by the opening of one conductor of a three-phase cable or line. That happening is so remote as not to be a significant factor. Therefore, it can be said that in the great majority of load-center power systems two motor overload relays will provide adequate motor overload protection when delta-wye transformers are used.

Further consideration of the problem need be given to only the small percentage of cases in which fuses, instead of three-phase breakers, are used in the primary of the load-center unit substation. Even in those few cases, however, it will be found that there is practically no risk in operating with only two overload elements in the motor-control circuit.

Historical Background

So far as motor overload protection during single-phasing of the primary is concerned, the problem is the same whether the power supply is from a delta-wye load-center unit substation or a wye-delta transformer combination with its primary wye ungrounded. Literally thousands of industrial plants are fed from utility systems with wye-delta transformer banks (4160 wye, for example) which are fused on the primary and sup-

plied through overhead lines, and hence are susceptible to single-phasing by fuse melting or line failure. Even so, the author is not aware of any recorded trouble of any significance in these plants due to motor burnout under primary single-phase conditions.

Code Requirements

In its Motor Control Section 4327, the National Electrical Code specifies that only two thermal protective devices are necessary, regardless of the type of transformer connection or the type of primary protection of the transformer.

Fuses Seldom Blow

In the few cases where fuses are installed at the transformer, they should blow only on the occurrence of a fault in the transformer, a condition which is very rare. Faults beyond the transformer are, in a properly coordinated system, cleared by the main secondary or feeder circuit breakers. Also, proper co-ordination usually requires rather high-rated fuses, relative to the transformer rating, which further reduces the possibility of one fuse opening except on transformer failure.

Two Transformations

Where there are two delta-wye transformations—for instance, 13.2-kv incoming, 4.16-kv distribution, and 480-volt utilization—a single-phase condition on the 13.2-kv system will result in a motor-operating condition that will be properly detected by two thermal overload relays. (See FIG. 2.)

(Continued on next page)

TABLE I
COMPARISON OF GROUNDED-NEUTRAL AND ISOLATED-NEUTRAL
480-VOLT SYSTEM OPERATION

Advantages of Grounded-neutral System	Disadvantages of Isolated-neutral System
<i>Safety</i>	
Only 277 volts to ground at any time (assuming good ground and 480 volts maximum line-to-line)	Although there is only 277 volts to ground when there is no ground fault on the system, there will be 480 volts to ground on two conductors if the other conductor becomes grounded
Secondary voltage is limited to about rated secondary voltage if primary-to-secondary failure occurs in transformer	Secondary voltage may become as high as primary voltage if primary-to-secondary failure occurs in transformer
Ground fault in control wiring can put only 58 percent of line voltage on line-to-line connected contactor closing coils	Control circuit ground fault likely to put full line voltage on contactor closing coils
<i>Service Reliability</i>	
Ground faults are readily located and removed without taking system out of service	Necessary to take system out of service to locate ground faults
Ground faults are localized and tripped off immediately	If the first ground fault is not removed, the occurrence of a second one will cause two circuits to go out at once and hence result in the loss of twice as much production
Floating grounds are very unlikely	Floating or arcing grounds are likely
<i>High-voltage Fluorescent Lighting Supply</i>	
Can be used directly at about \$20 per kva of lighting load	Must utilize step-down transformers from 480 to 264 volts or lower
<i>Operating Cost</i>	
Unnecessary to spend time locating ground faults	Time may have to be spent in locating ground faults
<i>First Cost</i>	
That of the grounded-neutral system is slightly higher—about one percent for the average substation	



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OVERLOAD PROTECTION

(Continued from preceding page)

All Motors Are Not Unprotected

When a delta-wye transformer bank becomes single-phased on the primary, it is probable that only about one-third of the motors and control on the secondary system will be so connected that the high current, resulting from the voltage unbalance, will fall in a phase which does not have a thermal overload relay. Only those motors will have inadequate protection against that overcurrent. The other two-thirds of the motors and control on the system will be so connected that the control will "see" the highest current in the three lines and thereby furnish proper protection to the motor. These statements are based on the assumption that phase designations are not carried through to the motor control and, therefore, that all control will not be connected in the same manner with respect to the phase lines; for example, phases A, B, and C will not always be connected to control terminals T1, T2, and T3 respectively.

Effect of Motor Loading

Motors which are not heavily loaded may run indefinitely on single-phase without undue heating, and in doing so they may act as single-phase to three-phase converters to correct the unbalanced conditions existing on more heavily loaded machines.

Easy Detection

In industrial plants, single-phase conditions would in all probability be detected and investigated immediately by workers in the area affected.

Grounding Secondary Has No Effect

The problem of motor thermal overload protection under primary single-phase conditions is not influenced by grounding or isolating the neutral of the secondary wye of the transformer.

CONCLUSIONS

There should be no doubt of the adequacy of two overload elements in the great majority of load-center systems, because in those systems power circuit breakers are used for primary protection. Also, there is usually no problem of practical significance in the few cases where primary fuses are used.

It should, of course, be remembered that theoretically damage can occur on single-phasing. Hence, in cases where a transformer bank is connected to a primary system that is likely to become single-phased, and the bank is used to supply only a few large motors (of the order of 100 hp or larger) or automatic unattended motors installations (such as in pumping stations, compressor rooms, and oil-field pumping equipments) care should be taken to see that each motor controller contains a motor thermal protective device in each phase in order to obtain adequate overcurrent protection of the motor.



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PUMPED RECTIFIERS IN 600-VOLT TRANSPORTATION SERVICE

Automatic operation and protective relaying are features of a reliable form of conversion in modernizing power supply and distribution systems in urban transportation substations

By RALPH SIEGEL

Power Electronics Division, Industrial Eng. Div.
General Electric Company



Ralph Siegel

RECTIFIERS for transportation power requirements have established themselves as a highly reliable means of conversion to d-c from an a-c supply. In keeping with this over-all high reliability there is the necessity for simplicity of control, protection, and switching. High reliability and simplicity have paved the way for automatic operation of the control and switching equipment. Consequently, most modern rectifier transportation substations are designed for fully automatic operation, and they require only routine inspection and maintenance (apart from attention given them upon the infrequent occurrence of a prolonged abnormal condition).

The control and protective equipment described in this article is applicable to power systems supplying substantially constant-voltage power to urban electric transportation and main-line systems. FIG. 1 shows a typical suburban substation; the COVER shows an arrangement of the conversion apparatus.

THE EQUIPMENT

A pumped rectifier unit consists of a fully co-ordinated equipment containing high-voltage a-c switchgear, a transformer section, a pumped ignitron rectifier, a d-c switching section, and auxiliary control. A typical line diagram of such a conversion unit is shown in FIG. 2.

A-C SWITCHGEAR

The a-c switchgear usually contains an a-c circuit breaker selected in accordance with the local system's interrupting capacity requirements, of suitable capacity to carry the a-c rectifier input during the two-hour rated overload, and with an interrupting time (at rated kva) of not more than 0.133 seconds. Also included is an auxiliary compartment containing a small step-down transformer to supply three-phase low-voltage power for the rectifier excitation, auxiliaries, and control. Provision of metering equipment, lightning protection, and suitable termination for incoming and outgoing service is made according to local requirements. The a-c switchgear is used to apply or remove the a-c supply to the rectifier unit.

RECTIFIER TRANSFORMER

The rectifier transformer has the d-c rating of the rectifier. Co-ordinated relaying and switching prevent this rating from being exceeded. The transformer performs three functions:

- (1). Transforms incoming a-c voltage to a value to provide proper d-c voltage output
- (2). Transforms the incoming number of phases to the number required by the rectifier for application
- (3). Usually provides the negative terminal for the d-c system.

RECTIFIER SECTION

The pumped ignitron-rectifier section consists of an assembly of single-anode tanks, each with anode heater; a complete evacuating system, vacuum-measuring equipment, a water-cooling system with either a water-to-water or water-to-air heat exchanger, protective devices, and excitation equipment. With the exception of the excitation equipment, and the water-to-air heat exchanger when it is used, all the foregoing devices are mounted on a single frame. The excitation equipment used in firing each of the tanks is mounted in a separate cabinet, located as close as possible to the rectifier. When a water-to-air heat exchanger is used, it, too, is separate from the rectifier but as close as possible to it.

D-C SWITCHGEAR AND RECTIFIER CONTROL

The d-c switching equipment usually includes an air circuit breaker of suitable capacity for the two-hour rating of the rectifier and for other system requirements. This air circuit breaker is connected between the d-c bus and the cathode of the rectifier and usually has an interrupting time of approximately 0.05 seconds. Higher-speed cathode breakers may be used, according to the particular application.

High-speed anode breakers are used in conjunction with medium-speed cathode breakers when the unit rating exceeds 2000-kw output and the d-c voltage does not exceed 900 volts. Anode breakers are also used where essential service and other requirements require their application. The d-c switchgear normally includes necessary auxiliary equipment for the d-c breaker.

This article is so paged that, without mutilating other articles, it can be readily removed for filing as a group of full-size consecutive pages.—EDITOR

Fig. 1

Fully automatic railway substation with mercury-arc rectifiers and metal-enclosed switchgear equipments



It should be noted that if the d-c system is grounded, the usual practice is to ground the negative. Whether grounded or not, the rectifier is solidly connected to the system negative, and breakers are only in the positive side of the circuit.

AUXILIARY CONTROL SECTION

The auxiliary control section contains the equipment necessary to control the auxiliaries of the rectifier. In this group are the disconnect switches and magnetic motor starters for the water-circulating pumps, blowers, vacuum equipment, and any other accessories which local conditions may require, such as refrigerator pumps and compressors. Also included are the contactors for energizing the firing circuits and anode and

water heaters. An annunciator, with its associated relays, is usually provided to facilitate trouble-shooting. Auxiliary relays for the water-pressure and thermostatic devices on the rectifier section, misfire relays, and degassing control are also mounted in the auxiliary control section.

AUTOMATIC OPERATION

STARTING

Before a fully automatic pumped-type rectifier is permitted to start, the control automatically checks all rectifier auxiliaries to make certain that they are in proper operating condition. This check insures that all the circuits that control the water heater, vacuum system, water-circulating pump, and any other necessary auxiliary motors are completed. These circuits are supplied from the three-phase auxiliary power transformer; thus, the control-power switches should be kept closed at all times so that the auxiliary devices are energized to keep the rectifier in the proper operating condition. Rectifier disconnecting switches, when used, must be closed. Breaker permissive switches should be closed and the annunciator checked to see that none of the annunciator drops is down. If the excitation selector switch is in the normal position, the rectifier is then ready to start.

A starting signal given either locally, or from a remote position by supervisory equipment, or by load-responsive equipment will automatically cause the following sequence of events:

- (1). The a-c power circuit breaker will close
- (2). At the same time, if the gas pressure within the tanks is sufficiently low, the excitation contactor will close to energize the ignition circuits. The ignitors begin to fire and the anodes conduct at the proper time. The rectifier will now be providing d-c voltage
- (3). If an anode breaker is used it will close immediately after the a-c breaker closes

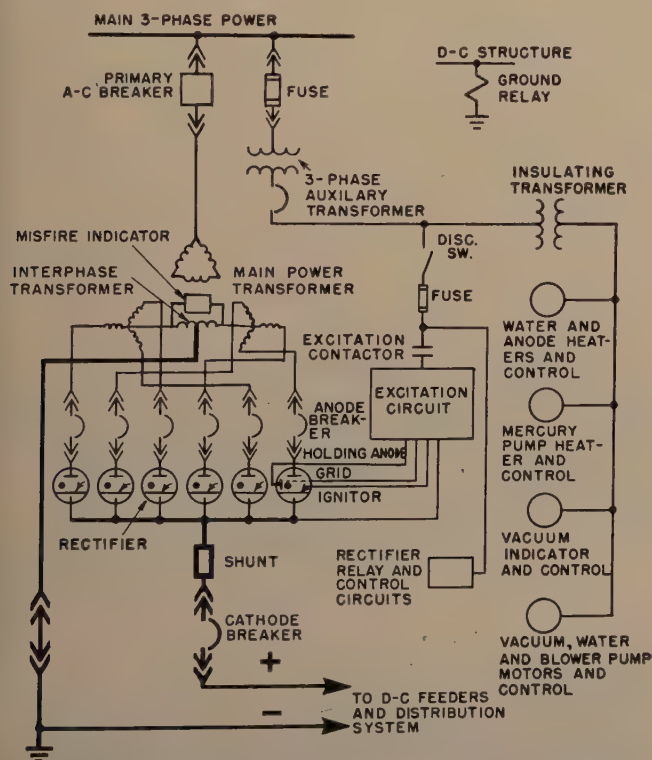


Fig. 2. Schematic diagram of a fully co-ordinated pumped ignitron rectifier installation

(4). The presence of d-c rectifier voltage will automatically close the d-c breaker

(5). The rectifier will then feed power to the d-c bus.

STOPPING

To shut down the rectifier a stop signal is given to the equipment locally, or by a supervisory circuit, or by load-responsive equipment. That signal will cause all the power circuit breakers to trip and the excitation circuits to be de-energized.

PROTECTION

Equipment is included to detect excessive overloads, arc-backs, and the conditions which cause arc-backs, and to protect the rectifier and the a-c and d-c systems from them. The protective devices will cause the rectifier to shut down and either will allow automatic starting again immediately after action has been taken to correct abnormal conditions or, upon the occurrence of the more serious types of abnormal conditions, will cause the rectifier to shut down and lock out. In the latter instance the lockout relay must be reset manually before the rectifier can again be started.

TEMPORARY OUTAGE CONDITIONS

The conditions that cause a temporary outage are frequently of such a nature that they are automatically corrected in the course of time, and the rectifier can then again supply the d-c bus with power. If these conditions are not immediately corrected the rectifier will stay shut down but in readiness to come on the line at such time as the abnormal condition disappears. Among such conditions are:

- (1). Improper water pressure or loss of water
- (2). Temperature of the water too high
- (3). Temperature of the water too low
- (4). Insufficient vacuum
- (5). Low- or single-phase a-c supply voltage
- (6). Reverse phase sequence for a-c supply voltage
- (7). Transformer overtemperature.

CONDITIONS CAUSING SHUTDOWN AND LOCKOUT

After shutdown and lockout of the rectifier an attendant must go to the station to service the equipment, correct the faulty condition, and manually reset the lockout relays so that the rectifier can again be started automatically.

A reclosing timing relay is used to reclose after arc-back in order to preserve continuity of service. It will start timing at the instant the rectifier ceases to operate after arc-back and will reclose the primary a-c breaker (which indirectly closes the cathode breaker) a predetermined number of times (usually once) after a set time of a few seconds. If the unit does not immediately arc back again, the breakers stay closed and the rectifier will continue to supply power to the bus. If the unit continues to arc back, the rectifier will be shut down and locked out.

If an anode breaker is used, the recloser will reclose any of the individual poles which trip on arc-back (usually not more than one or two poles of the anode breaker open, and service is not interrupted) instead of the main a-c circuit breaker. Lockout will follow if the rectifier arcs back again immediately after a reclosure, but the poles which do not arc back will be sealed in by the lockout relay. Thus an indication is given as to which tanks have arced back. It should be noted that the a-c breaker and the cathode breaker will also be tripped and locked out by the action of the lockout relay.

The conditions that cause the rectifier to shut down in the manner described are:

- (1). Arc-back
- (2). Misfire for longer than the predetermined length of time
- (3). D-c short circuit not cleared by sectionalizing equipment
- (4). Uncompleted sequence of operation
- (5). Severe a-c overcurrent.

Misfire

When prolonged misfire occurs—that is, when a rectifier anode fails to conduct—an induction-type time-delay relay trips the a-c breaker and, in turn, the cathode breaker. The recloser makes the usual number of attempts to restore service, but if the misfire persists the lockout relay will lock out the rectifier. If an anode breaker is used, only the anode breaker is tripped and reclosed. However, if the misfire persists, the primary, the cathode, and the anode breakers will all be locked out.

D-c Short Circuit

A d-c short circuit, if not removed by feeder or sectionalizing equipment, will cause the a-c breaker to trip. That breaker then goes through its reclosing cycle. Lockout will follow if the fault is not removed.

Structural Ground Faults

Structural ground faults are dangerous because they may raise the potential level of the structure to that of the rectifier cathode. Consequently, a ground-detection relay is included to trip and lock out the primary breaker immediately upon the occurrence of such a fault. The anode breaker, if used, the cathode breaker, and all feeder breakers will also be tripped and locked out.

Uncompleted Sequence

When a rectifier is put on the line the usual sequence of events, after the starting signal is given, begins with the closing of the primary breaker; this causes the cathode breaker to close. (The primary breaker is closed indirectly by the energizing of a master contactor, which in turn starts the recloser timer to close the a-c breaker.) Since the closing of the cathode breaker interrupts the circuit to the lockout relay, if the cathode

breaker does not close within a definite time the entire equipment is locked out of service. Consequently the sequence of operation must be completed or lockout results.

Severe A-c Overcurrent

Severe a-c overcurrent will open the a-c breaker. When this happens the d-c breaker will automatically open, disconnecting the rectifier from the bus. The recloser then goes through its time cycle, and if the a-c breaker continues to trip out after the recloser recloses it, the rectifier will be locked out. The use of an anode breaker changes the sequence somewhat: the rectifier is locked out immediately after the occurrence of a fault condition that trips the a-c breaker.

Severe a-c overcurrents seldom occur, but may be caused by internal faults in the transformer or by faults in connections from the transformer to the a-c switchgear. These short-circuits are detected by inverse time-delay overcurrent relays set to normally ride over the transformer inrush current.

OTHER PROTECTIVE FEATURES

A third type of protection, which does not involve the stopping of the rectifier, is overvoltage on the d-c bus. Overvoltage is caused by d-c power regeneration when traction equipment uses regenerative braking on down grades. Since a rectifier is not capable of reversing current direction, the voltage may rise on the d-c bus to a high value unless a load-absorbing equipment is connected to the system. The means normally used to prevent undue overvoltage are:

- (1). Other loads connected to the bus, capable of absorbing the regenerated power
- (2). A load resistor connected to the bus only at such time as overvoltage is present.

Sometimes it is not possible to have sufficient load available to absorb regeneration on the bus; for that condition the second means must be employed. A voltage-sensitive relay, which responds to rise in d-c bus voltage, is used to operate a high-speed contactor and connect a resistor to the bus. A feeling-out action then takes place whereby the resistor is disconnected

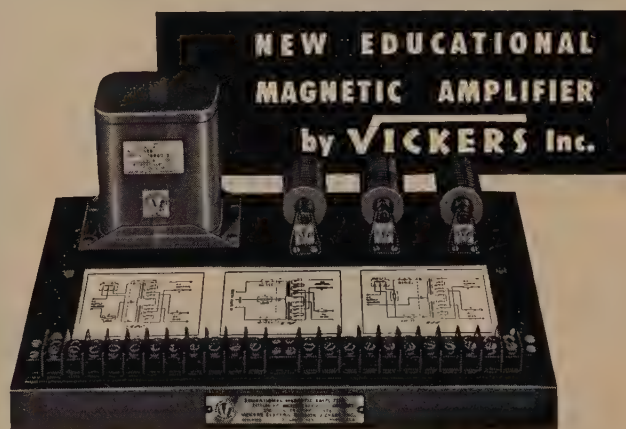
and reconnected to the bus at regular intervals until the overvoltage is no longer present. The resistor, being placed across the bus, holds the d-c voltage to approximately the normal value.

PARALLELING AND SELECTIVE OPERATION

Paralleling of rectifiers on the bus is easily arranged. Attention to the need for increased interrupting capacity of the d-c cathode breakers is, of course, necessary. Co-ordinated selective relaying and switching equipment may be provided so that infrequent faults in one rectifier will have no ill effect on other equipment on the same bus. Service usually will not be interrupted by an arc-back if the switching equipment is properly selected and relayed. When paralleled with other types of conversion equipment, the rectifier can be made to share the load on any practical basis that may be desired.

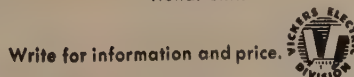
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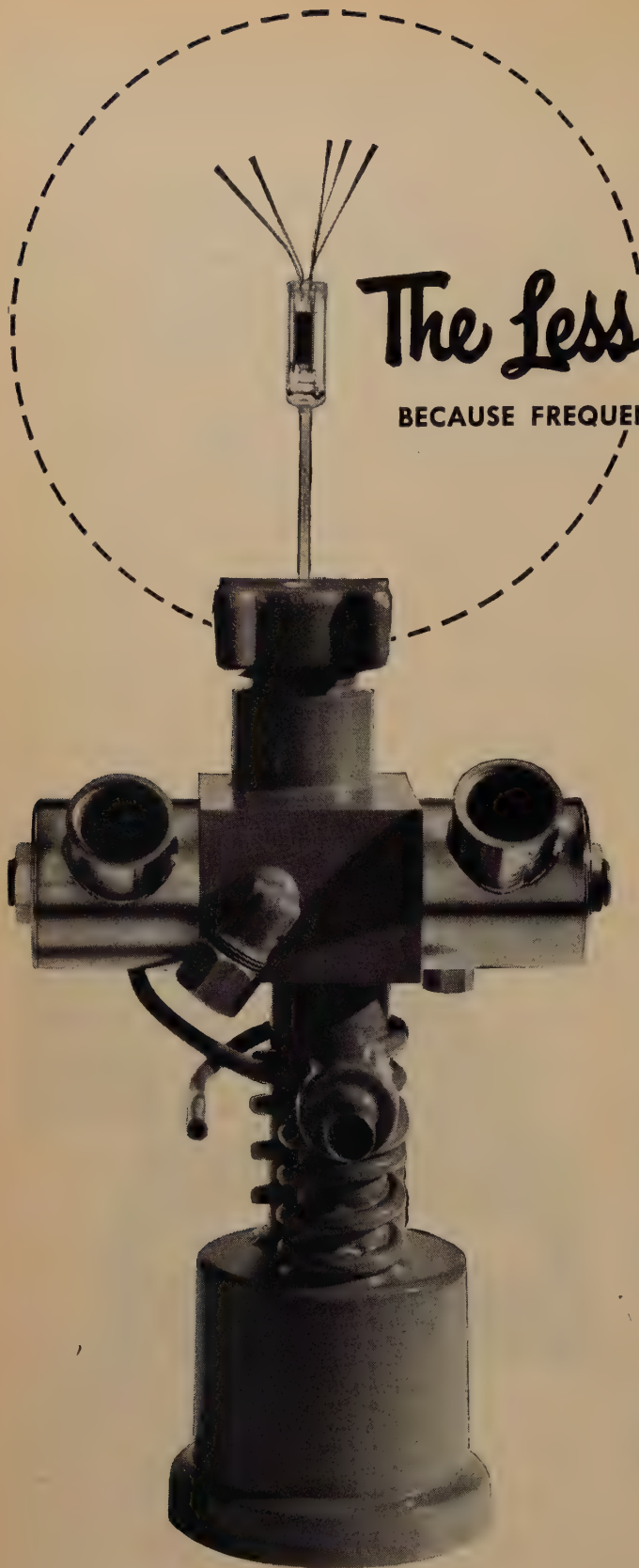
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EVOLUTION OF TRANSFORMER GASKETS

The discovery of a resilient material capable of resisting the rigors of temperature, pressure, deformation, and solvent effects assures long-term protection of liquid insulation and gives substantial savings in materials and assembly time

By L. P. HART, Jr.

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General Electric Company, Pittsfield, Mass.



L. P. Hart, Jr.

THERE is a large class of electrical apparatus that is filled with insulating liquids. The liquids provide a means of cooling and insulating such devices as power transformers, distribution transformers, and voltage regulators. Construction of this equipment involves the use of tanks, covers, radiators, and bushings. The joining of these components is accomplished in most cases by the use of a gasket. The gasket must be made of a relatively soft, resilient, deformable material that will function as a sealing means between two surfaces. Ideally it should prevent entrance of moisture into the unit and completely retain the insulating liquid.

One of the earliest materials used as a transformer gasket was felt. This was a soft, deformable material of limited resiliency that functioned at best as a splash-proof type of seal and actually provided little permanent protection against moisture transmission. It could not be used successfully below the oil level in a transformer. Felts impregnated with various resins followed and were somewhat less porous, but they were even less resilient.

A better sealing mechanism was that provided by the use of glue-bonded composition cork. This was considerably less pervious to oil and moisture and when used with a protective adhesive provided a very useful sealing mechanism. A further improvement in gasket life was accomplished by the use of synthetic-resin-bonded composition cork.⁽¹⁾

Subsequently there was developed a composition of cork and Neoprene, which was much less pervious to liquids and moisture. Because this material, like composition cork, had a relatively high compression set its best use required the application of an adhesive. The adhesive served to bond the gasket to the adjacent surfaces so that a permanent seal was obtained even though the gasket lost its ability to exert a back pressure on the sealed surfaces. In certain applications the adhesive actually caused the gasket to increase in thickness much like an accordion when the gasketed

(1) Numbered references are listed at the end of the article.

This article is so paged that, without mutilating other articles, it can be readily removed for filing as a group of full-size consecutive pages.—EDITOR

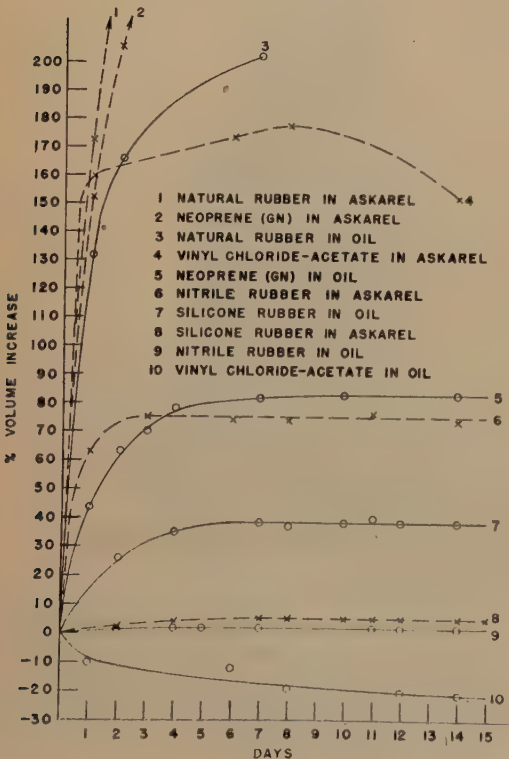


Fig. 1(a). Volume change of various materials in transformer oil and askarel at 100 C

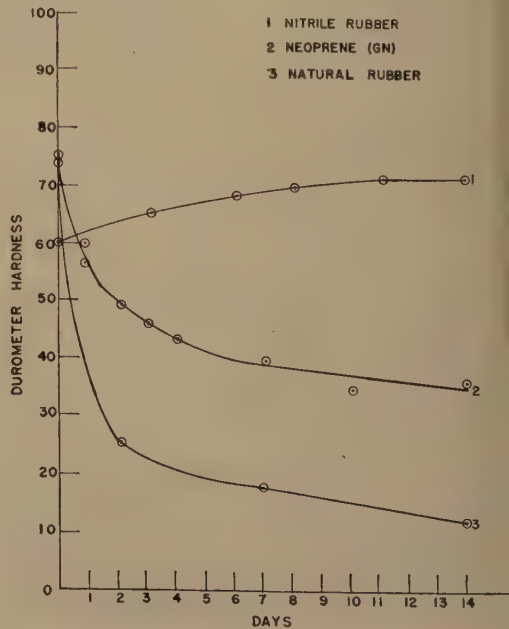


Fig. 1(b). Durometer hardness change of three rubber-like materials in transformer oil at 100 C

surfaces moved apart. The movement of gasketed surfaces is nearly always encountered on large transformer tanks as the cover flexes up and down depending upon internal pressure changes which result from changes in transformer temperature.

Another difficulty observed with Neoprene—cork gaskets where no adhesive was used resulted from the change in resiliency with temperature. Joints that were tight during warm weather leaked oil badly during cold weather because the gasket did not have sufficient resiliency to overcome the shrinkage caused by the lower temperature.

Both composition cork and Neoprene—cork compounds, which required the use of adhesives, were tedious to apply, sometimes involving eighteen to twenty-four hours of assembly time. Furthermore, when units were disassembled, gaskets were always torn apart and had to be completely replaced.

It was recognized at this point that a rubber-like material would be almost ideal for gasketing purposes. Rubber is resilient, has long life, and is not readily permeated by moisture. Therefore, an active investigation was started in the Transformer and Allied Products Laboratory to evaluate rubber-like materials for these specialized gasket applications.

BEHAVIOR OF RUBBER-LIKE MATERIALS IN OIL AND ASKAREL

In the process of this work it was first necessary to evolve tools and methods for studying the behavior of gasket materials in the presence of transformer oil and askarel. One of the first tests used was simply to immerse a small sample of the material being studied in a quantity of the insulating liquid and qualitatively examine its condition after a period of heating. By this simple expedient it was soon determined that natural rubber compounds are badly attacked by oil or askarel. They swell to a gelatinous mass and retain very little of their original properties.

As the work became more exacting, the following test procedure was adopted for screen testing. A sample of rubber-like material 2 in. long by 1 in. wide by approximately 0.075 in. thick was immersed in approximately three ounces of the insulating liquid. In closed containers the samples were aged at 100 C. Periodically they were removed, washed in solvent, dried, and their weight and volume determined using a Jolly balance. By comparing these figures with the original, it was possible to plot curves showing the rate of volume or weight change with time. Some typical curves of various materials are shown in FIGS. 1(a) and 1(b).

The volume-change curves give an almost exact picture of the resistance of the various materials to the solvent action of oil and askarel. The oil-resistant natural-rubber compound referred to in FIG. 1 was swollen rapidly to a state where it retained only a small percentage of its original properties. There was almost a total loss of tensile strength, and the durometer hardness dropped from 75 to 12 after fourteen days in

100 C oil. These figures confirmed in a more quantitative way the preliminary observation of the change to a gelatinous state.

The Neoprene compound was severely attacked by askarel as shown by Curve 2 in FIG. 1(a). In oil, the volume increase was appreciable; but the swelling reached a maximum and the volume remained constant thereafter. The fact that the curve levels off is important as it indicates the material reaches a steady state after only a partial loss of original properties.

In askarel, the vinyl chloride-acetate compound was swollen badly; and then the volume began to decrease. This decrease was caused by the actual dissolving of the compound. In oil, the vinyl chloride-acetate material shrank badly, which indicated that the oil was leeching out plasticizer. The shrinking was accompanied by an extreme hardening of the compound.

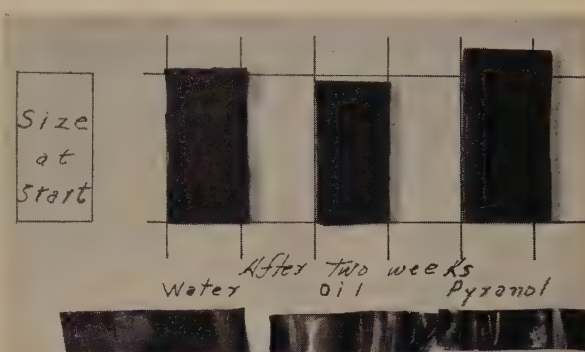


Fig. 2. Screen test samples of nitrile rubber after two weeks' immersion in water, oil, and askarel (Pyranol). Note shrinkage and swelling

The nitrile rubber compound (FIG. 2) showed excellent resistance to oil attack and was as little affected by askarel as Neoprene was by oil. *For the first time then it appeared that a rubber-like gasket material was available which might be usable in oil and askarel.* This was a significant discovery, and it became the basis of an intensive study of nitrile-rubber compounds.

When these investigations were originally undertaken, silicone rubber compounds were not available; but the data which were accumulated later are shown here. It is interesting to note the amazing resistance of silicone to askarel, the increase in volume amounting to only 5 percent in two weeks' aging. The silicone compound was not as resistant to attack by oil.

NITRILE RUBBER COMPOUNDS

The discovery of the resistance of nitrile rubber to askarel led logically to the study of other synthetic rubbers of the nitrile rubber type. This class of rubbers is often referred to as Buna N, and the base material consists of a copolymer of acrylonitrile and butadiene.

A study was made to determine the effect of the ratio of butadiene and acrylonitrile content upon resistance to oil and askarel. Curves for three polymers (samples A, B, and C) are shown in FIG. 3. These samples were compounded with the same plasticizers and general ingredients to give similar durometer hardnesses.

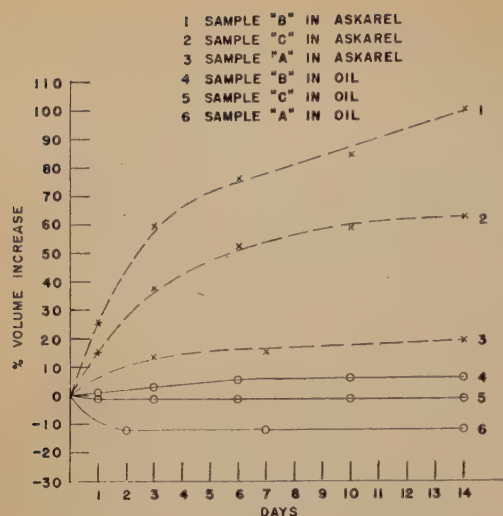


Fig. 3. Volume change of nitrile-type synthetic rubber in transformer oil and askarel at 100 C

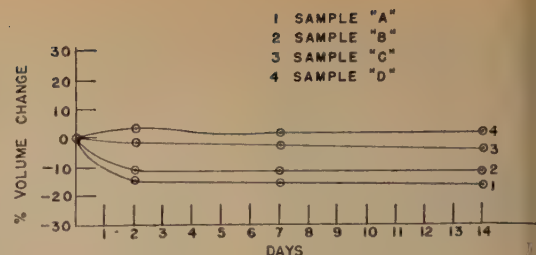


Fig. 4. Effect of plasticizer on volume change of nitrile-type synthetic rubber samples of 65 durometer hardness in transformer oil at 100 C

An examination of the curves in FIG. 3 indicates that nitrile rubber Sample A had the least volume change in askarel. This happened to be the copolymer with the highest acrylonitrile content. Nitrile rubber Sample B, which had the lowest acrylonitrile content, also had the poorest resistance. In oil, however, the nitrile rubber Sample A shrank about 12 percent in volume and remained constant. This then posed the problem that the material which seemed to be most resistant to askarel was not well suited for use in oil, because of shrinkage.

After some investigation it was found that the shrinkage in oil was due to extraction of plasticizer by the hot oil. A study was then made of the effect of plasticizers on volume change in oil. Some results are shown in FIG. 4. These are typical of the great number of curves actually observed. As the work progressed, it became apparent that some plasticizers were available which functioned efficiently and which were not extracted. These are represented by Curve 4.

CONTAMINATION

Another important requirement which a transformer gasket material must fulfill is that it must not cause electrical contamination of the insulating liquids such as oil and askarel. Contamination of the insulating liquids can result in a harmful decrease in dielectric strength, an unwanted change in power factor, or a lowering of resistivity. It was necessary to submit all the compounds investigated to standard contamination tests in oil and askarel.

The oil contamination test involves aging a standard-size sample in a given quantity of transformer oil at 120 C for two weeks. At the end of this time the oil is checked for sludge and acidity. A sample of the oil is then aged in a bomb for a period of time to determine whether any harmful material has dissolved in the oil that will promote decomposition over a long period of time. It became apparent that certain ingredients commonly used in synthetic-rubber compounding were very harmful to the oil. It was then necessary to run an extensive series of tests to determine which compound-

ing ingredients, such as plasticizers, softeners, vulcanizing agents, and accelerators, could be used. It was finally possible to develop a satisfactory finished compound which would not contaminate oil.

The compounds, to be generally used, had also to pass contamination tests in askarel. Askarel is a chlorinated aromatic compound and when hot is a very active solvent. The problem of selecting compounding ingredients that were usable with askarel was even more difficult than with oil. Nevertheless, after extensive testing it was possible to find the necessary components to make a synthetic-rubber compound which could be used in oil and askarel as well.

Actually this compound was unique in that no other known rubber-like material could be used with both oil and askarel.

MECHANICAL PROPERTIES

Hardness

With some assurance that a synthetic-rubber gasket having satisfactory resistance to oil and askarel could

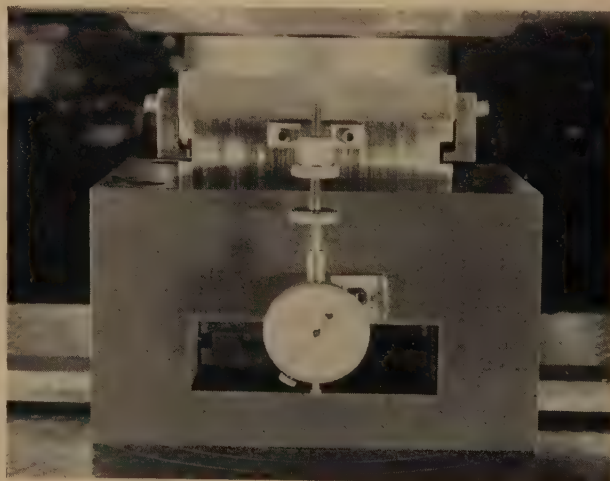
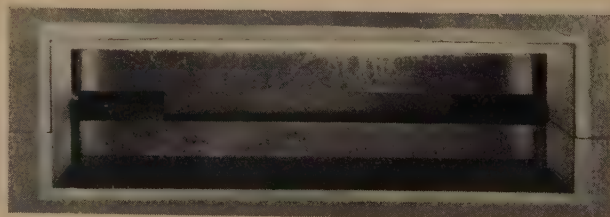


Fig. 5. Test equipment for deforming gasket material samples to obtain load-deflection curves. The close-up view (below) of the test fixture shows a sample in place



be found, it was necessary then to determine a suitable hardness for the gasket. A specialized practice had been followed for some time using a Neoprene—cork composition gasket having a cross section of $\frac{3}{8}$ in. by $\frac{3}{4}$ in. in a machined groove $\frac{1}{4}$ in. deep by 1 in. wide, and it seemed logical to maintain these groove dimensions for nitrile rubber. Since rubber does not compress materially, but flows, a suitable cross-sectional dimension for synthetic rubber was calculated to be $\frac{3}{8}$ in. by $\frac{5}{8}$ in.

It was also calculated that a suitable gasket deforming force would be 1000 psi of original gasket area. To determine the dynamic deformability characteristics of nitrile rubber having the newly established cross

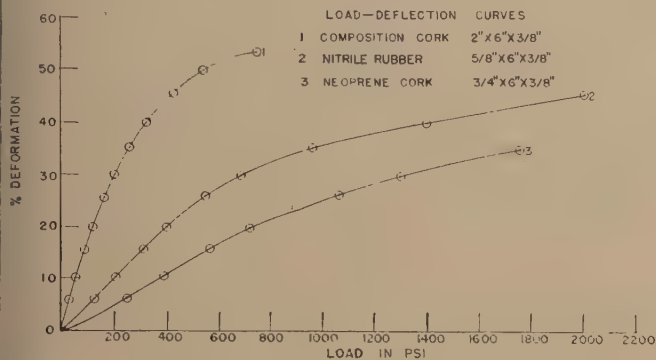


Fig. 6. Load-deflection curves for samples of gasket materials

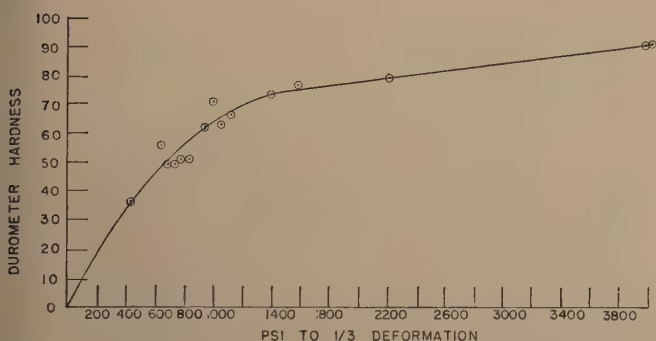


Fig. 7. Durometer hardness vs dynamic deformability of nitrile rubber compounds

section, the following was done: Load-deflection curves were run, using a Baldwin Southwark testing machine equipped with a suitable sub-platen (FIG. 5). Specimens were 6-in. long by the indicated cross section. Load was applied at the rate of approximately 200 psi of area for the nitrile rubber compounds. Typical curves are shown in FIG. 6. To relate the dynamic deformability to the more readily measured durometer hardness (Shore Type A), a series of load-deflection curves were run on nitrile rubber of several hardnesses. These results are shown in FIG. 7, which indicates that a dynamic deformability of 1000 psi corresponds to a durometer hardness of 65. Further development work was carried on, therefore, with compounds having a nominal durometer hardness of 65.

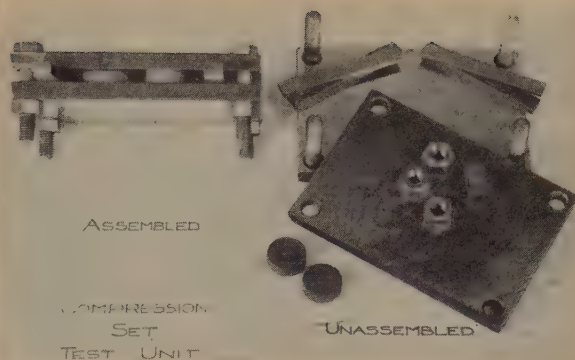


Fig. 8. For tests of compression set, samples are clamped between chromium-plated steel plates

Compression Set

In the development of synthetic rubber gasket materials it was apparent that some method was needed for measuring the ability of the material to maintain back pressure over a period of time. A method for determining the compression-set characteristics of rubber-like materials had been developed by ASTM Committee D-11. This method is known as D395. As written, there are two alternative methods of making the measurement. One of the methods involves a measurement under constant deflection. In view of the fact that most transformer gasket applications involve a constant deflection rather than a constant load, this method was selected. For this work, compression-set buttons, either molded directly or cut from sheets of synthetic rubber were used. These buttons were $1\frac{1}{8}$ in. in diameter and $\frac{1}{2}$ in. thick. They were compressed between flat chromium-plated steel plates to fixed spacers (FIG. 8). In these tests a deflection of 33 percent was used. The clamped specimens were then heated in an oven for 70 hr at 100 C. At the end of this time the fixture was unclamped and the specimens allowed to cool for 30 min on a laboratory bench top. Thickness measurements were made before and after each test with a dial micrometer. The compression set was expressed as a percentage of the original deflection and was calculated as follows:

$$\text{Percent compression set} = \frac{(A - C)}{(A - B)} \times 100$$

where A = original thickness of specimen

B = compressed thickness of specimen

C = final thickness of specimen

Based on a test such as this, the following compression sets were observed for a good grade of composition cork, for a Neoprene—cork composition, and an early nitrile rubber sample.

Material	Percent Compression Set
Composition cork	98
Neoprene—cork	82
Nitrile rubber	69

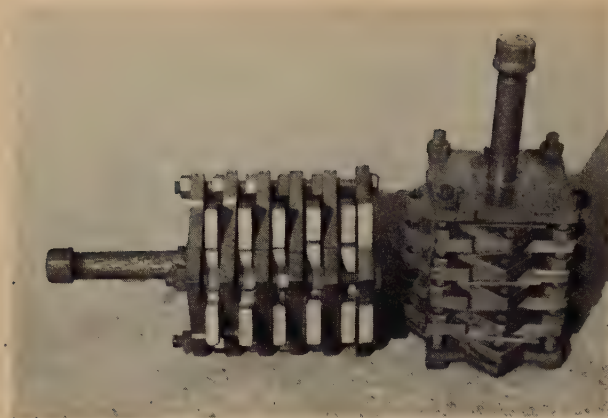


Fig. 9. Test unit for gasket service tests in which samples can be subjected to the effects of heated liquid under pressure

These figures were related qualitatively to the performance of gaskets in a service-test unit. The service-test unit consisted of a series of steel plates which could be assembled with gaskets between them into a fixture, shown in FIG. 9. The fixture had a reservoir that was filled with transformer oil and air pressure of 20 psi applied over the oil. The whole assembly was then placed in a container of water and heated at 80 C for five days. It was then removed and allowed to stand at room temperature for two days. This cycle was repeated a total of four times, giving a total exposure of 28 days. Such an arrangement simulated a severe exposure of a transformer gasket with hot oil on the inner edge of the gasket and hot water on the outer edge.

In these tests it was observed that composition cork gaskets always developed leaks or showed serious signs of oil penetration. The only way to make a satisfactorily sealed joint with cork was to apply a heavy coating of adhesive. The adhesive served to bond the cork surfaces to the steel plates and protected the inner edge from oil entry and the outer edge from exposure to water.

Neoprene—cork compositions gave satisfactory results only by the use of an adhesive to fasten the gasket surfaces to the steel plates. Otherwise, the compression set of the material was so high that back pressure against the plates was lost and oil leaked by.

In the nitrile rubber gaskets there was no evidence of oil leakage, attack by oil, or attack by water. The nitrile rubber gasket was somewhat deformed and did not return to its original shape. However, subsequent tests run on hundreds of these nitrile rubber gaskets have not produced a single instance of gasket failure. These tests were also repeated with askarel instead of oil on the inside surface of the test fixture. Approximately the same results were noted except that the Neoprene—cork was very seriously deteriorated because of the solvent action of askarel on the material.

It is interesting to note the improvement that has been made in the compression-set characteristics of the nitrile rubber compounds during the period 1941 to 1948. This improvement has been brought about

primarily by improved skill in compounding. Nitrile rubber compounds with compression sets as low as 20 percent are now available. This improvement is indicated in FIG. 10.

The coefficient of expansion of nitrile rubber is shown in FIG. 11. This plot gives an average value of 7.8×10^{-5} in. per in. per deg C.

Permeability to Water Vapor

To establish the rate at which moisture vapor would pass through a nitrile rubber compound that was suitable for use as gasket material, the following test was performed:

A glass cylinder 10 cm in diameter and 11 cm high was covered on both ends by nitrile rubber disks 0.215 in. thick. The disks were clamped in place with metal flanges. A small hole drilled in the side of the glass cylinder contained a sealed-in rubber stopper and two stopcocks which were used for sampling. The apparatus was airtight as determined by testing under high vacuum.

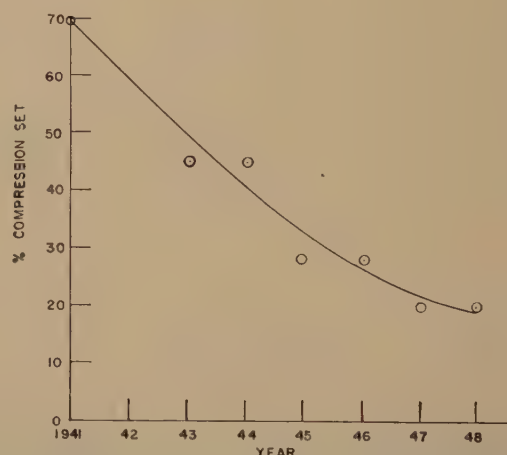


Fig. 10. Graphic record showing improvement in compression-set characteristics as developments continued over a period of years

The cylinder was 80 percent filled with dry insulating oil and placed in an oven at 40 C and 65 percent relative humidity. At suitable time intervals, samples of oil were withdrawn and their water content measured by titration with Karl-Fischer reagent.

Results obtained are as follows:

Time (days)	Water in Oil (parts per million)
0	3
3	33
6	48
18	65
56	62

From such data it is possible to calculate a diffusion constant for water vapor through nitrile rubber. This has been determined as 8.5×10^{-8} grams per sq cm per cm per hour per mm of Hg difference in partial pres-

tures, which compares with 7×10^{-8} reported by Taylor, Herman, and Kemp⁽²⁾ for natural rubber.

This diffusion constant can easily be given practical application. For instance, it has been calculated that a 500-kva transformer using askarel and nitrile rubber gaskets and exposed continuously to relative humidity of 50 percent for one year could not absorb in excess of 0.0015 lb of water, which is equivalent to 0.5 parts per million of water in the askarel. This is a negligible amount and represents a much more extreme case than is likely to be encountered in service.

SERVICE TESTS

As the work with nitrile rubber continued, a great many accelerated aging tests were run. Some of these have already been referred to but others are of interest. In one instance, gasket assemblies were made up where in the gaskets had an internal gas pressure of 100 psi. They were subjected to alternate cycles of 150 C heating and -40 C cooling. Nitrile rubber withstood many such cycles without any drop in pressure as measured at room temperature. No other gaskets tested would withstand more than one cycle.

In another test, assemblies were made up with the inner edge of the gaskets exposed to oil. The assemblies were subjected to a cycle involving 5 days at 150 C and 2 days at -30 C.

At the end of each cycle the units were tested with gas pressure of 20 psi over the oil. Results are as follows:

Gasket	No. of Cycles without Leaks
Composition Cork	none
Neoprene—cork	one
Nitrile rubber	twelve plus

The same assemblies of nitrile rubber that passed the cycle test have been allowed to age continuously at 80 C. No leaks have developed after three years at this temperature.

In 1941 fifteen distribution transformer tanks were made up with nitrile gaskets. These tanks were filled

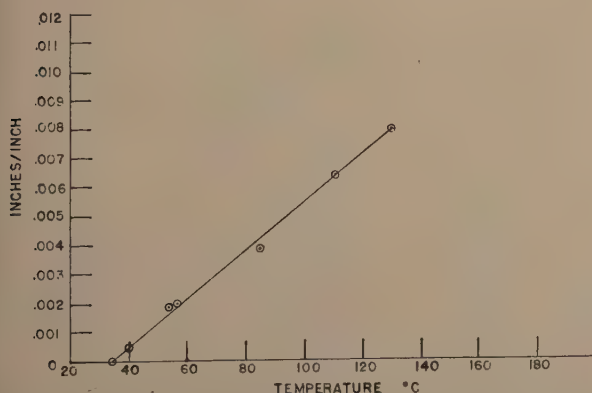


Fig. 11. Coefficient of expansion of nitrile rubber is shown to be 7.8×10^{-5} in. per in. per deg C in this plot

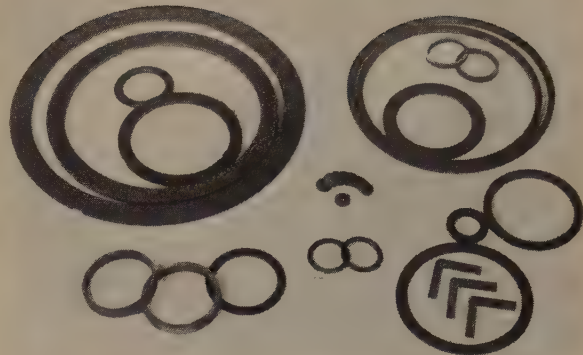


Fig. 12. Some typical nitrile rubber gaskets for electric equipment

and inverted so that there was a head of oil of about three feet against the cover gasket. These tanks have been exposed outdoors for over eight years, and no leaks have developed. Composition cork gaskets for the same application were considered satisfactory if they did not leak after 24 hours on such a test.

APPLICATIONS

The first use of nitrile gaskets on liquid-filled electrical equipment was made in the early 1940's. High-voltage bushings, power transformers, and induction regulators were assembled with nitrile gaskets during 1941 and put into service. The usage increased during 1942 and continued to increase slowly during the war years. Large-scale changeovers were not possible during the war because the amount of nitrile rubber available was limited and because engineering and drafting time could not be spared to change designs.

After the war, however, gasket practice was changed rapidly to utilize the new rubber. Nitrile-rubber-gasket procurement for transformers and allied products increased about seven times in the three years after the war. Nitrile rubber gaskets are now standard on many liquid-filled transformers, bushings, and voltage regulators (FIGS. 12, 13, and 14).

Basically, the cost of nitrile rubber is about three or four times that of composition cork. Nevertheless, in most cases noticeable economies were effected by the use of the rubber-like material. As an example, a strip of rubber $\frac{3}{8}$ in. by $\frac{5}{8}$ in. in cross section replaced a strip of composition cork $\frac{3}{8}$ in. by 2 in. Furthermore, the use of adhesives at the time of assembly of the apparatus was eliminated with a very substantial reduction in labor costs. But still more important is the fact that a rubber gasket is used many times without being destroyed. Previously, a composition cork gasket was used for leak testing one type of transformer tank after fabrication. This had to be cemented between the cover and the tank. It was destroyed when the cover was removed. After testing the assembled transformer, another cork gasket was destroyed when the tank was opened for inspection. A third gasket was used for



Fig. 13. Oil-immersed distribution transformer in which twelve nitrile rubber gaskets are used

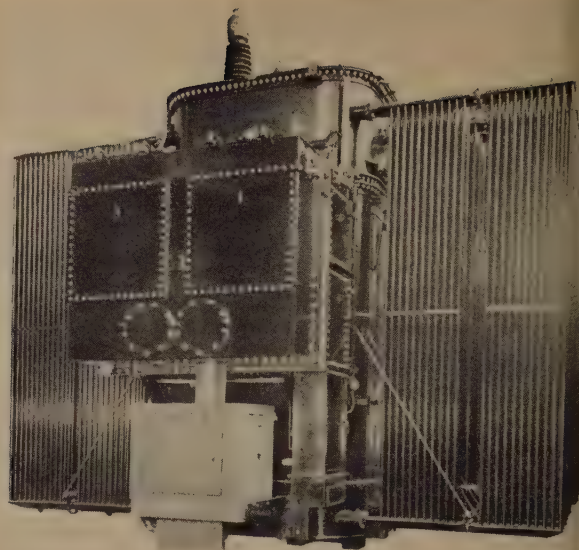


Fig. 14. Power transformer in which nitrile rubber gaskets are used on cover, bushings, tank section, radiators, and load-ratio-control boxes

shipping purposes and a fourth one was usually shipped as a spare.

The present practice is to use only one rubber gasket and to ship no spares; so, in effect, one nitrile rubber gasket is replacing four cork gaskets. Since the nitrile gasket has a cross sectional area only one-third that of the cork, the ratio of cork to rubber is 12 to 1, which means that the rubber gasket costs only about one-third or one-fourth as much as composition cork for the same application. Furthermore, there are bonuses in the form of reduced labor, shorter assembly time, and much higher quality.

The sealing mechanism of the nitrile gaskets is much superior to the old cork-adhesive combinations. With cork it was the practice to first coat the gasket completely with a red Glyptal adhesive. This was allowed to air dry overnight. The tank, flanges, and cover were also coated with adhesive which was allowed to dry. Then a second coat of adhesive was applied to the gasket and mating surfaces. When the adhesive was at the proper stage of tackiness, the surfaces were joined. This operation was one requiring much skill on the part of the workman and a careful laboratory control of the adhesive. Metal pieces had to be carefully cleaned and free of paint so that the adhesive would adhere. On big units it was very difficult to work over such a large area and have the adhesive at the proper tacky stage at all points. The starting point was apt to be too dry and the finish point too wet. If the adhesive were wet, the gasket was likely to slip and the whole operation would have to be repeated. The seal, then, was almost completely dependent upon doing a good adhesive job. This was not always accomplished.

With rubber, on the other hand, a preassembled gasket is laid in place and the assembly bolted as most convenient. On vertical surfaces the gasket may be tacked in spots with an adhesive especially developed for this purpose. This operation takes only ten minutes.

The resiliency of the gasket is such that a permanent seal will be maintained, and there is a safety factor. With time, the rubber develops a moderate bond to the metal surfaces. In askarel-filled units there is a further safety factor in that the askarel tends to swell the nitrile rubber slightly.

The preassembly of large rubber gaskets is accomplished in the same manner as with composition cork. Strips and corner pieces are carefully scarfed on a suitable device, adhesive is applied, allowed to dry five to ten minutes and then the surfaces are pressed together. With rubber, the joint is immediately quite strong and cannot be pulled apart by hand. To remove any uncertainty about the joint quality, however, it is vulcanized under heat and pressure. Joints properly prepared in this fashion have about 90 percent of the strength of the rubber itself.

SUMMARY

The study of the gasketing problem on liquid-filled electrical apparatus led to the conclusion that a rubber-like material offered the best possible solution to the problem. A thorough survey of such materials showed that nitrile rubber was the most promising type of compound for such gasket applications. An active development program in conjunction with several rubber companies produced compounds which met the following requirements:

- (1). Resistance to attack by hot oil and askarel
- (2). Freedom from contaminating effect on the electrical properties of insulating liquids
- (3). Excellent compression-set characteristics
- (4). Satisfactory aging characteristics
- (5). Low moisture vapor permeability
- (6). Low cost.

The application of nitrile rubber gaskets to transformers and other liquid-filled electrical apparatus has resulted in the following advantages:

(1). The virtual elimination of gasket leakage. Since the introduction of nitrile rubber, leakage attributable to gasket materials has been reduced to a point where it is negligible. By this writing there are over 5,000,000 nitrile rubber gaskets in service in General Electric transformers and related products

(2). A permanency of seal which was hitherto unknown. Moisture is excluded from sealed units in a virtually perfect manner and oil is permanently retained

(3). A reduction in assembly time. The time required to install gaskets on a large transformer has been reduced from twenty-four hours to three or four hours. This is particularly important in assembling units in the field

(4). A lowering of cost. Because one nitrile gasket of much smaller cross-sectional area is used where several cork gaskets were required, a substantial economy has resulted. The practical elimination of the use of adhesives has lowered costs and increased dependability.

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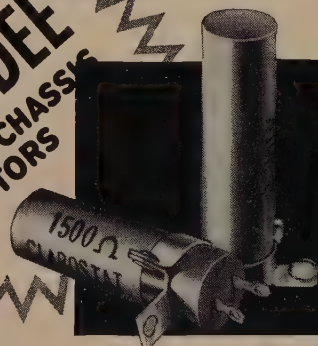
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OPTICAL CONTOUR FOLLOWER

New device for controlling operation of a machine tool to reproduce accurately the curve shown in a drawing, with noteworthy economy in production of master patterns

By T. M. BERRY

General Engineering and Consulting Laboratory
General Electric Company



T. M. Berry

THE optical contour-follower control is an automatic curve-following device. It has several unique features which make it ideally suited for use as a machine-tool control for the purpose of reproducing, in metal, a shape designated on a line drawing.

A number of machine-tool controls of the template-follower type are in general use for machining duplicates from a metal master pattern. The optical contour follower is used in making the master pattern itself.

In many cases thousands of duplicates are made from a single metal master, and only a few masters are required. The amount of time and labor involved in making these few accurate masters is relatively unimportant. Developmental manufacturing, however, requires that a master be duplicated only a relatively few times and that a much larger number of masters be made. In this case the time and labor involved in making a master is very important. It was for the purpose of reducing this time and labor that the optical contour follower (FRONTISPIECE) was developed, in the General Engineering and Consulting Laboratory of the General Electric Company.

DIFFICULTIES OF TEMPLATE METHOD

The systems in general use for making metal masters are laborious and time-consuming. They are beset with many difficulties not at first apparent. For example, in making a three-dimensional metal master, the usual steps are about as follows:

An accurate scale drawing is made of each of a number of sections. These are usually drawn enlarged for accuracy and scribed on glass for dimensional stability.

A smooth curve is drawn, representing the shape and size of each section; a sufficient number of points on this curve are selected to allow a machinist to produce a smooth curve between the selected points on a metal template when it is cut to size at these points only. A complete set of dimensions must be furnished to the machinist which will allow him to cut to the curve accurately at the desired points.

The dimensions given to the machinist are not the distances from two co-ordinate axes to the points on the curve, but the distances from two co-ordinate axes to the points on the travel of the center of a cutting

tool which will cut the template. If the same shape is to be cut in a different size it requires a new set of dimensions and may require a cutting tool of a different size. If the cutting tool changes in size because of wear, the machined template will be in error.

After the required number of templates have been cut, and faired between cuts by hand, a template follower may be used to control a machine tool that reproduces these template shapes on the three-dimensional master at the proper station levels on the master. The surplus metal between cut sections on the master is then removed with hand tools, and the master is completed.

IMPROVED METHOD—FASTER, SIMPLER

In contrast with this method, the use of the optical contour follower involves the following procedure:

After the accurate enlarged drawing of the desired shape is scribed on glass, it is photographically reproduced on a steel plate, appearing as a black line on a white background.

This steel plate is then placed in the optical contour follower, where the scanner picks up the line and follows around the curve. The contour follower automatically controls a machine tool which reproduces the shape of the curve directly on the metal master. This gives the desired section at one station. When the required number of sections are cut, the master is faired between sections by hand, and the job is finished.

A simple adjustment will permit the use of different-sized cutting tools. This same adjustment is used to compensate for tool wear; it can also be used for taking a rough cut on the first run of a curve, and then a finish cut on the second run, removing the same amount of metal all the way around.

PRINCIPLE OF OPERATION

The operation of the optical contour follower can be explained by referring to a schematic representation of the system (FIG. 1). An optical scanner is carried on the end of an arm which is rotatable. The center of rotation of the arm is moved around the curve by means of two lead screws X and Y at right angles to each other. The scanner arm remains normal to the curve at the point of scanning.

The lead screws are automatically power-driven to make the scanner move along the curve, and the

This article is so pagged that, without mutilating other articles, it can be readily removed for filing as a group of full-size consecutive pages.—EDITOR

scanning arm is automatically controlled to maintain its right-angle relationship to the curve at all times.

The lead screws of the contour follower are coupled to the lead screws of the machine tool by power selsyns, through gear reducers. The machine tool reproduces the shape of the drawn curve because the length of the scanner arm corresponds to the radius of the cutting tool, and the tool cuts at a point on the reproduced curve corresponding to the point of scanning on the line drawing.

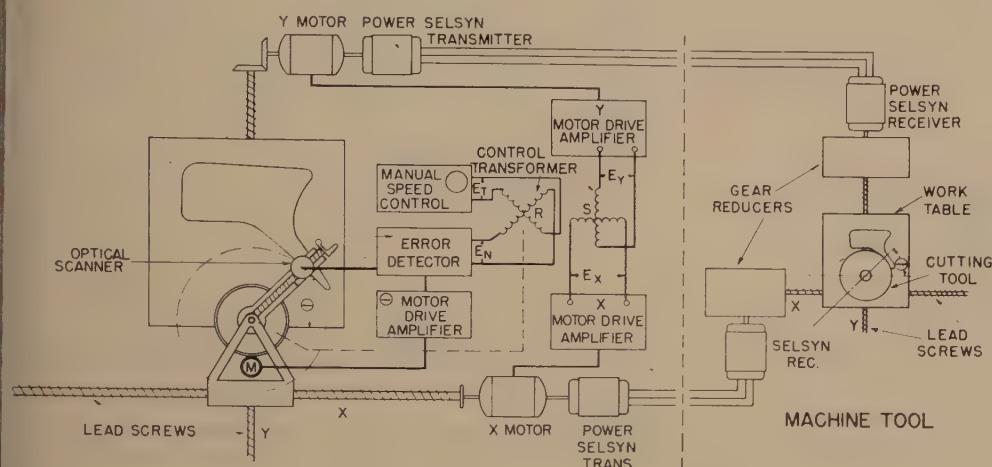


Fig. 1
Functional diagram of
optical contour follower

Change gears are used to obtain different ratios between the drawing and the machined parts. To operate the contour follower, the operator puts in the proper change gears to give the desired size reduction between the drawing and the machined section. After adjusting the length of the scanning arm to the equivalent radius of the cutting tool, he indexes the machine tool and contour follower to the proper starting point by manual controls.

The scanning arm is then rotated by a manual control to point at the curve to be reproduced. The operator throws a switch to a semiautomatic position and turns the manual speed-control knob. The scanner will move toward or away from the curve, as desired. When the scanner "sees" the curve, all motion will stop.

The operator then throws a switch, the scanner centers itself on the line, and the scanning arm automatically adjusts itself to be normal to the curve. As the manual speed-control knob is turned up, the scanner moves along the curve at an adjustable rate up to six inches per minute, remaining centered on the curve and keeping the scanning arm normal to it.

OPERATION OF SCANNER

As shown by the schematic drawing (FIG. 2), the optical scanner consists of an 1800-rpm synchronous motor with a hollow shaft in which is mounted a dove prism. At one end of the shaft is a microscope objective lens, and at the other end is an opaque plate with a small aperture displaced from the center of rotation of the shaft.

The line under the microscope objective lens is illuminated, and the lens system focuses an enlarged image of a small section of the line on the aperture

plate. As the shaft of the motor rotates, the dove prism is rotated. This rotates or spins the image of the line past the aperture at twice the speed of rotation of the motor.

A phototube, placed behind the aperture, picks up the light passing through it. When the line image falls on the aperture the light is decreased, causing voltage pulses in the output of the phototube amplifier. These voltage pulses are used to fire two thyratrons whose anode voltages are 180 degrees out of phase. When the

image of the line is on the center of rotation of the scanning motor armature, and the scanning arm is normal to the line being scanned, both thyratrons fire at the peak of the 60-cycle voltage wave. FIG. 3 shows a sketch of the line image in four positions for each of three conditions and the timing of the light pulsations for each condition. The dark area under the sine curve represents the current being drawn by thyratrons No. 1 and No. 2 alternately.

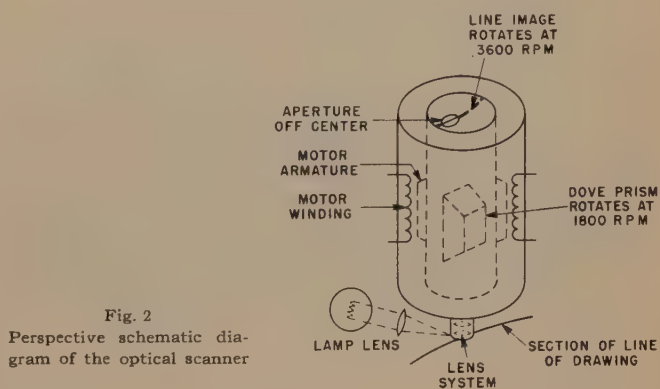


Fig. 2
Perspective schematic diagram of the optical scanner

As can be seen in FIG. 3(A), the voltage pulses produced when the line is on center and normal to the curve are equally spaced and occur at the peaks of the 60-cycle voltage. If the whole scanner is not normal to the line but is rotated clockwise as shown in FIG. 3(B), the voltage pulses are still equally spaced but occur later in each cycle, causing the current through both thyratrons to decrease. If the scanner is rotated counter-clockwise, the voltage pulses would occur earlier in the cycle and both thyratrons would draw more current.

FIG. 3(C) shows the timing of the voltage pulses when the scanner is not centered on the line. In this case the voltage pulse caused by one end of the line image crossing the aperture will occur later and the pulse from the other end of the line will occur earlier. Both the pulse spacing and the current in the thyratrons will be unequal.

Thyratron 1 will have less current than thyratron 2 if the line is off the center of the scanner as shown in FIG. 3(C). If the line is on the other side of center, thyratron 1 will draw more current than thyratron 2. The total current drawn by both thyratrons will be the same as in FIG. 3(A), the on-center on-line condition.

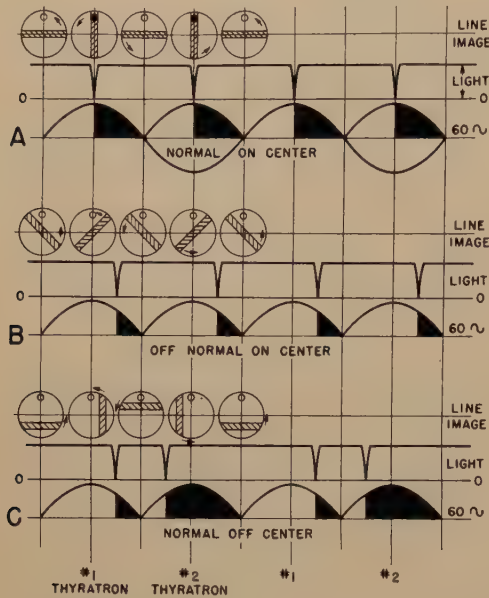


Fig. 3. Image of the line in four positions in the scanner for each of three conditions, and the timing of light pulsations, together with corresponding currents (dark areas) drawn by thyratrons

The sum of the thyatron currents is an indication of the angle the scanning arm makes with the normal to the curve; the difference of the thyatron currents is an indication of how far the center of the scanner is from the line. Thus is provided the intelligence by which the scanner is kept centered on the line and the scanning arm normal to it. Three servo systems must act to maintain these conditions, one maintaining the angular error of the scanning arm at zero.

CORRECTIONS

Since an off-line condition usually must be corrected by two motors acting through the X and Y lead screws, the error signal must be split into the proper X and Y components of error. This is accomplished in the following manner:

The d-c error signal caused by an off-center condition is first changed to an a-c voltage which changes phase 180 deg to indicate direction and changes amplitude to indicate the distance of the line off center.

As shown in FIG. 1, the a-c error signal E_N is applied to one rotor winding of a control transformer. Both the

rotor and stator of this control transformer have two windings that are at right angles to each other. The rotor is mechanically coupled to the scanning arm, and turns with it. It is so adjusted that the voltages induced in the two stator windings by E_N are:

$$E_Y = E_N \sin \theta \quad \text{and} \quad E_X = E_N \cos \theta.$$

E_X and E_Y cause the X and Y servo motors to correct an error properly no matter where the scanner is on the curve.

Besides correcting off-center errors, the X and Y motors move the scanner along the line. This requires only that a voltage be applied across the second rotor winding of the control transformer. If the error signal E_N causes the scanner to move in a direction normal to the line, a voltage E_T on the other rotor winding, which is at right angles, will cause the scanner to move along the line.

ADJUSTMENTS

The voltage E_T is manually adjustable to control the speed of motion along the line; reversing the phase of this voltage causes the scanner to travel in the opposite direction along the line. If no errors existed in this manual control system the X and Y servo systems would not be necessary. The motor speeds are largely controlled by the manual control; the off-center error signal E_N is just enough to compensate for errors in the manual system.

Over-all accuracy of the optical contour follower is such that it will follow a straight line on the drawing to ± 0.003 in. when following along the line at the rate of six inches per minute. The scanning arm will adjust itself to within plus or minus one degree from the normal to the curve.

An error will occur when the scanner follows around a curve which has a small radius of curvature. The aperture of the scanner is off center about 0.3 in., and the optic magnification is approximately 8. This gives an effective scanning circle of 0.04-in. radius. Any curve which has a radius of curvature approaching 0.04 in. will be reproduced with a small error, because of the fact that the scanner centers on the straight line joining the two ends of the line image.

CONTROL

FIG. 4 is a simplified schematic diagram of the circuits of the control system. A two-stage amplifier amplifies the pulse signals from the phototube, which fire thyratrons T_1 and T_2 as previously explained. The angular error signal E_θ appears as a function of the sum of the currents in T_1 and T_2 across R_1 , which is in series with both cathodes.

In the anode circuits of T_1 and T_2 are two saturable-core reactors L_1 and L_2 forming two legs of an inductance bridge. The unbalance voltage of this bridge provides the voltage E_N , which is connected to the control-transformer rotor winding and which causes the off-line correction, as explained earlier.

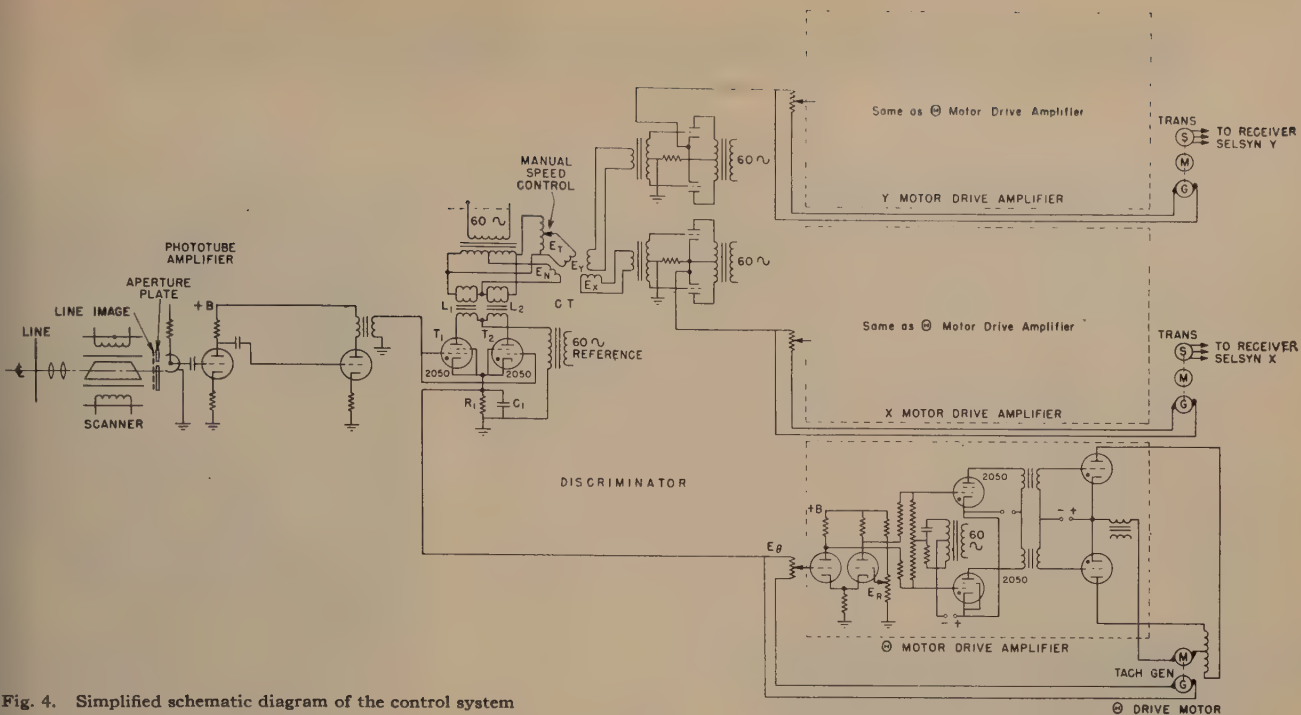


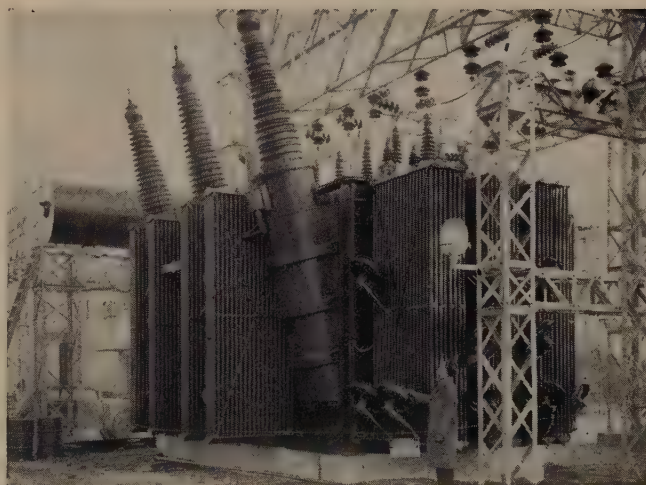
Fig. 4. Simplified schematic diagram of the control system

The X and Y components E_X and E_Y , which combine the voltages E_N and E_T , are connected to the grids of grid-controlled rectifiers to supply a d-c voltage input to the motor-drive amplifiers. A balanced amplifier circuit in the motor-drive amplifiers controls the firing of two small thyratrons that in turn control the firing of two FG95 power thyratrons.

The FG95 thyratrons control the current to 1/4-hp split-field series motors; tachometer generators driven by these motors provide speed control and some stabilization of the servo systems. The capacitor C_1 provides filtering for the d-c voltage across R_1 and helps compensate for the inherent time lag in L_1 and L_2 . Other feedback circuits, not shown, are used in the balanced amplifier circuit of the motor-drive amplifiers for additional stabilization.

Although all three servo systems are acting on the scanning mechanism at the same time and each servo system is capable of causing errors in the other two, it was not found necessary to provide any cross stabiliza-

tion in the servo loops. This is no doubt due to the fact that, within operating limits, the errors produced by the operation of the θ servo system in the other two are second-order-effect errors and that the motor-speed corrections required to keep the scanner on the line were relatively very slow.



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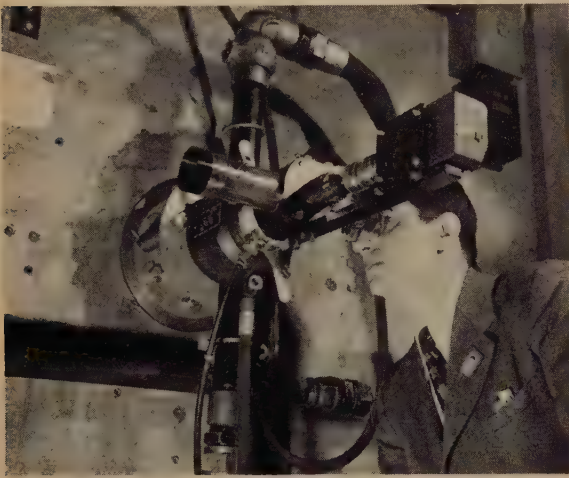
A water-cooled, 12-ft periscope for looking into the fiery exhaust of a jet engine has been developed for use in a test chamber. Its quarter-ton steel cylinder, one end of which is placed ten feet behind the jet engine being studied, allows engineers to watch the pattern of burning gases in the 2500-degree exhaust blast.

The periscope is jacketed in thick stainless steel, beneath which is a 45-gallon-per-minute water-cooling system for carrying away the terrific exhaust heat.

A quartz window, both air- and water-cooled, looks directly into the exhaust

cone of the engine while the air-cooling system blows a stream of cold air over the window, preventing the exhaust gases from reaching it. The periscope is mounted in a well in such a manner that engineers are able to observe while protected from the exhaust.

Image of the burning gases is transmitted through the tube to observers by means of a conventional optical system. On the viewers' end of the periscope are a 16-mm motion picture camera, an eyepiece for an observer, and a large, television-like screen which several persons may watch.



Action inside the jet engine is recorded in color by the motion picture camera mounted beside the observer's head

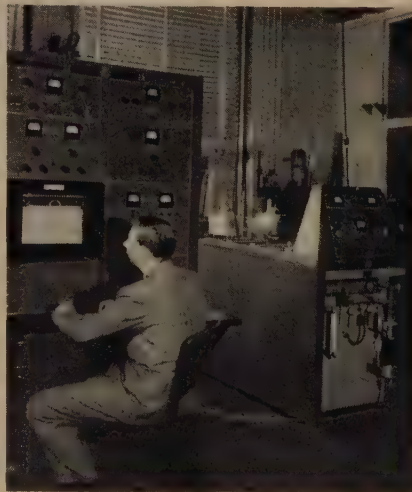
Studies of New Techniques in Weather Forecasting

Information being obtained by means of the analytical mass spectrometer will be used in new studies of the composition of the earth's atmosphere, which may lead to the development of new weather-forecasting techniques.

The high-sensitivity range of the mass spectrometer will aid in the study of reactions which meteorologists believe take place among constituents of the atmosphere as a result of absorption of radiant solar energy.

Under some conditions the mass spectrometer can detect a gas which is only 1/100,000 part of mixture. In operation, the gas to be analyzed is introduced into an ionization chamber, where its molecular particles are given electric charges. The molecules are then accelerated through a magnetic field which changes the direction of their movement; the lighter molecules are deflected to a greater extent than the heavier ones. Thus molecules of the gas under analysis can be spread across the instrument's collector plate in a molecular pattern according to their weights. Weights from 1 to 300 can be separated.

Because it separates molecules of different weights, or masses, the instrument is useful in recording the presence of isotopes. Scientists will use the instrument to seek upper-atmosphere isotopes which have not yet been discovered.



Weights of molecules in gas are automatically recorded on the chart on the control panel

Measuring Compressor Output



By air blasting through these bell-like nozzles, mounted on a wall separating two airtight chambers, airflow from jet-engine compressors is measured. The compressor under test forces air into one chamber. From the number of nozzles opened to let air flow from one chamber to the other, and from the pressure drop between chambers, the volume of air per minute put out by the compressor is computed

Prospecting by Aircraft

Hunting sunken ships and surveying vast areas for iron deposits are among the possible peacetime uses of a modification of a device known as a magnetometer.

The instrument is sensitive to slight variations in the earth's magnetic field, such as those caused by iron deposits in the ground, or by large metallic objects, such as sunken ships. It was developed in part during World War II as an antisubmarine device for spotting enemy undersea craft from airplanes, and will not be made commercially available at the present time.

The instrument consists of a detecting coil, which produces a current proportional to the strength of the earth's magnetic field, and equipment for measuring variations in the current so produced. As the magnetometer-equipped plane moves through the earth's field, changes in the current flowing from the coil are indications that metal or iron minerals are distorting the field at that point, provided that the detecting coil has been kept in a constant position relative to the field.

A mechanism in the device controls the position of a gyroscope rotor, which in turn keeps the detecting coil in alignment with the earth's field. If the coil departs from the proper position, a compensating current is set up immediately to correct the measurements taken.

NEW PRODUCTS: AND WHAT THEIR MAKERS HAVE TO SAY ABOUT THEM

Air Meter

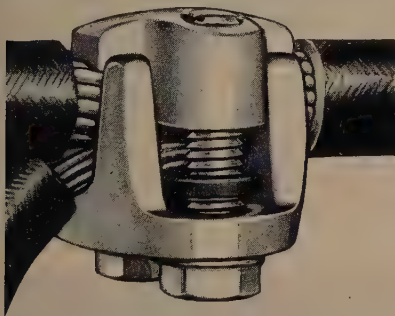
A new air meter, Model G, for instantaneous, direct, accurate readings of air velocities from 5 to 6000 fpm with an expanded scale in the low-velocity ranges. The instrument is now available with built-in temperature compensation to prevent momentary error in velocity reading



when the probe is subjected to sudden changes of temperature. It should prove useful in the air-conditioning industry, in process control, and in research installations in which it is desired to obtain readings quickly.—*Hastings Instrument Co., Inc., Hampton, Va.*

Clamp Connector

A new heavy-duty two-bolt clamp connector, called the Penn-Tap for taps and splices, service entrance connections, dead ends, etc.—indoor or out. This sturdily



constructed fitting has heavier sections of silicon-bronze alloy. It is quickly installed with an ordinary wrench, and is self-locking, holding tight permanently. There are no loose parts, and the fitting swivels on one locked bolt. Recessed bolts assure easy tapping.—*Penn-Union Electric Corp., Erie, Pa.*

Silicone Compounds

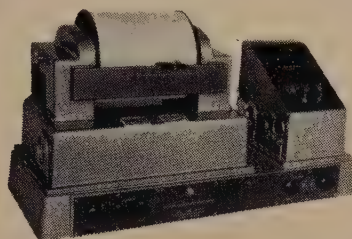
Several new silicone compounds for special applications: Two of these compounds, known as No. 13011 and 13012, are for use in extreme temperature applications for shock mounts, light spring-loaded gaskets, damping devices, etc. Compound No. 13013, of interest to specialty fabricators, has molding and extruding properties. Compound No. 12810 consists of a silicone resin

and glass-fiber filler. Outstanding heat resistance is its principal feature, thus making it suitable for circuit breaker, switchgear, and other applications where resistance to extreme heat and impact is necessary.

Silicones are used also in a new solution known as Stopall, Type C and CP, for treating concrete and cement-block buildings to keep water out. This particular solution is manufactured by the Stopall Waterproofing Manufacturers, Inc., Kalamazoo, Michigan. Its use also permits oil painting on concrete with lasting results.—*General Electric Co., Chemical Department, Pittsfield, Mass.*

Spectrophotometer

A new double-beam infrared spectrophotometer, Model 21, with a wide range of operating variables designed to serve the structural chemist for high resolution and sensitivity, and the analytical chemist for speed and accuracy. It records directly in



percent transmission against a linear wavelength scale on large readable charts. Its speed of scanning ranges from 3 min to 100 hr for rock-salt regions. Time response varies from a few seconds to more than a minute for full-scale deflections. The overall range of the instrument is less than 2 microns to 15 microns in the rock-salt region.—*Perkin-Elmer Corp., Glenbrook, Conn.*

Torch

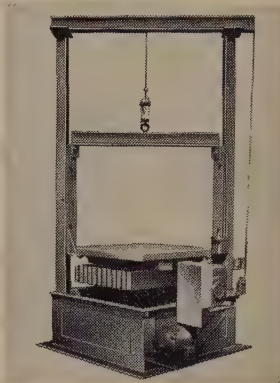
A new half-pint self-pressure torch—No. 59 for gasoline and No. 60 for alcohol—has many large-torch features. Complete with soldering-iron rest and windshield, it is practical for a wide variety of indoor home uses, light shop work, or hobbycraft work.



The $3\frac{1}{2}$ -in. diameter of the high-polished heavy-gage brass tank minimizes tipping. The tank holds $7\frac{1}{2}$ oz. of fuel and the torch will burn $3\frac{1}{2}$ hr full open at a temperature of 1700 F by pyrometer reading. A pump is not required because a brass wire interwoven with the wick conducts heat from burner into the tank.—*Turner Brass Works, Sycamore, Ill.*

Shock-testing Machine

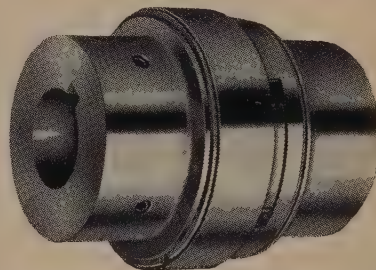
The Type 150 VD impact shock machine comprises a base with 4-ft square sand box, platform to carry the equipment being tested, an electric hoist, and uprights to guide the platform in its substantially free fall from the desired height. The platform will handle equipment as large as 36 in. by



36 in. by 30 in. high, weighing up to 150 lb. Steel-sheathed blocks, attached to the under-side of the platform, penetrate the sand at the end of the drop to give a single deceleration pulse without rebound. The number and arrangement of blocks governs the decelerating force and the duration of the pulse. Calibration curves show the relation between height of fall, maximum deceleration, and duration of deceleration pulse for various arrangements of control blocks.—*Barry Corp., 1190 Sidney St., Cambridge, Mass.*

Flexible Coupling

The improved L-R Type C and H couplings designed for use on motor-driven or engine-driven pumps offers extra ease of installation and larger bore capacities. The inside sleeve of these new couplings is made in two parts, instead of one, providing a sleeve in each body. Both bodies are



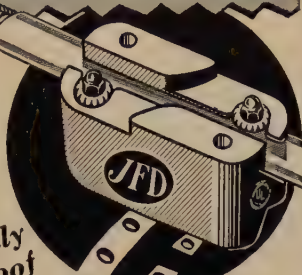
machined alike for the removable steel collar; thus bodies are interchangeable and the collar attaches easily on either half of the coupling. A snap-ring holds the collar in place. The couplings adjust for misalignment, shock vibration, oscillation, surge, or backlash. Also, half of the cushions are idlers (except on reversing load); hence there is always a set of new cushions in the coupling. Couplings are available with several types of cushion materials, each adapted to a particular service, from $\frac{1}{8}$ hp to 2500 hp.—*Lovejoy Flexible Coupling Company, 5001 W. Lake Street, Chicago 44, Ill.*

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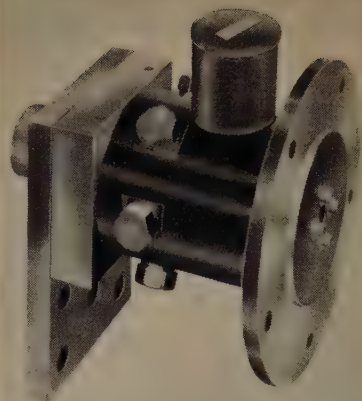
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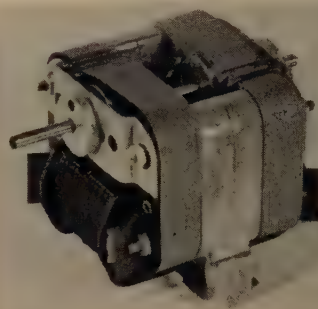
Collector Head

A new collector head transmits high currents from a stationary to a rotating member, replacing copper carbon brushes used in transmitting current in the electro-plate tinning line in the steel industry. The device insures long life with negligible brush drop because of the inherent design and quality of high conducting materials. The over-all efficiency of the head is high since its resistance is less than 10 microhms. This particular head is rated 10,000 amp, continuous d-c, 12 volts, 400 rpm; however, heads with different ratings can be supplied.—Sciaky Bros., Inc., 4915 West 67th St., Chicago 38, Ill.



Tandem Motors

A new Barcol Dyab tandem motor with high torque and excellent speed-torque characteristics. For wire recorders, vending machines, measuring instruments, positioning mechanisms, and other applications requiring a reversible unit. Maximum output is 0.004 hp. Carefully proportioned field and concentricity of rotor in stator result in smooth operation. The centerless-ground stainless-steel shaft is supported in wick-type bearings. The motor is available with several shaft diameters and various shaft extensions. Similar motors with 0.006-hp output are also available.—Barber-Colman Co., Rockford, Ill.



Megohm Meter

Two new megohm meters, L-4A and L-2A, with internal circuit which assures user that the applied voltage is the specified voltage as long as the resistance of the test piece is within the range of the meter. In this manner tests can be conducted with a known voltage.

Model L-4A contains an internal 500-volt measuring source, as well as a 200-volt source. Model L-2A has a continuously variable measuring source, ranging from 100- to 600-volt d-c. A voltmeter is provided for checking actual voltage being applied to test. With this model it is possible to test a piece for actual resistance changes as the voltage varies.—Industrial Instruments, Inc., 17 Pollock Ave., Jersey City 5, N. J.



Traffic Controller

A new expansible traffic controller, Type F, to meet most present-day traffic needs also can be easily adapted to meet growing traffic-handling demands. It is designed for wide application in the field of pre-timed traffic control, whether interconnected or noninterconnected. Engineered for flexibility, the controller can be installed with any other unitized type of controller in an existing system. To handle more complex traffic problems, jack-mounted dial units can be added when required.

Each dial unit is operated by a Telechron synchronous motor with built-in reduction gearing and lifetime-sealed oil supply. For easy and complete accessibility, the timer assembly is mounted on a pantograph table. The entire assembly can be removed by disconnecting an electrical plug and loosening two mechanical disconnects.—General Electric Co., Lighting and Rectifier Divisions, Schenectady 5, N. Y.



TRADE LITERATURE

AIR-RECOVERY UNITS—The purpose, function, construction, application, operation, and service of Type C air-recovery or purification cells for reclaiming odorous conditioned air is outlined in a comprehensive manner. Specifications, arrangement details, and capacity and resistance curves are also included. Sixteen pages. Bulletin 117-C.—*W. B. Connor Engineering Corp., 116 East 32nd St., New York 16, N. Y.*

COMPRESSORS—A thorough description of a new line of modern package-type heavy-duty electric-driven XLE compressors of advanced L-design. Complete with rating-data charts, installation photographs, and cross-section views. Eighteen pages. Form 3150.—*Ingersoll-Rand Co., 11 Broadway, New York 4, N. Y.*

CRANES—A pictorial two-color bulletin titled "How Whiting Cranes are Serving the Utilities" illustrates the variety of cranes built in a half-century of service to the power industry and lists over 350 powerhouse crane installations. Eight pages. Sec. 300—Unit 73.—*Whiting Corp., Harvey, Ill.*

ELECTRICAL CONTACTS—In addition to six pages of fundamental notes for contact design, there is detailed information about electrical contact materials, their properties, advantages, and uses. Of special value is the presentation of practical assembly methods, including riveting, spinning, upsetting, spot and projection welding, and brazing. Thirty-six pages.—*Fansteel Metallurgical Corp., North Chicago, Ill.*

INDUSTRIAL ELEVATORS—A new edition describing an entire line of elevators has been revised to include the low-priced Hundred Line portable elevators available in 500-, 1000-, and 2000-lb capacity. Portable cranes with fixed or revolving base, and hand and electric hoists are also presented. Thirty-six pages. Bulletin 4951.—*Barrett-Cravens Co., 4609 S. Western Blvd. Chicago 9, Ill.*

INFRARED OVEN—Describes an infrared oven for quick, economical controlled heating. Suggested applications include armature and stator baking, office equipment and appliance refinishing, bonding of brake linings, experimental laboratory work, miscellaneous batch heating jobs. Four pages. Form 72-648-150.—*Fostoria Pressed Steel Corp., Fostoria, Ohio*

OIL SEALS—A handbook of useful data on where to use and how to install J-M Clipper seals. Drawings show how the lip-and-heel construction of these nonmetallic oil seals can be varied, and the text contains other pertinent data of importance to designers, engineers, and maintenance men. Sixteen pages. Titled "Clipper Seal."—*Johns-Manville, 22 East 40 St., New York 16, N. Y.*

PORTABLE ELECTRIC TOOLS—Brief descriptions of the Super 40 and 50 grinder-millers and a complete line of other machine-tool mounts for finishing, sharpening, drilling, etc. at very high speeds. Six pages; 9 in. by 4 in. folder.—*Precise Products Co., 1328-30 Clark St., Racine 4, Wisconsin*

PRECISION INSTRUMENTS—Many new precision instruments for use in nuclear measurements are described in a new and complete catalog also containing some of the older instruments in this line. Each item is illustrated and accompanied by a detailed description. Several accessories are also included. Forty pages. Catalog K.—*Nuclear Instrument and Chemical Corp., 223 West Erie St., Chicago 10, Illinois.*

SYNCHRONOUS GENERATORS—An illustrated bulletin describing generators for standby, portable, and prime source power in widespread fields of application. Contains information on three typical installations, Tri-Clad construction features, protection, mechanical modifications, and performance data. Eight pages. GEA-5415.—*General Electric Co., Apparatus Dept., Schenectady 5, N. Y.*

TEMPERATURE INDICATORS—A brochure describing a line of temperature-indicating products. Directions for use and typical applications for Tempilstiks, Tempilaq, and Tempil Pellets are given. Six pages 3¼ in. by 8½ in. Catalog No. 501.—*Tempil Corp., 132 West 22 St., New York 11, N. Y.*

WELDING ELECTRODE COMPARATOR—A pocket-size welding electrode comparator slide-rule chart listing the rods and electrodes, and indicating the type of service for which each is designed. Publication No. GEN-37.—*General Electric Co., Schenectady 5, N. Y.*

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- Television Signal Synthesizer
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- Field intensity equipment
- Television test equipment

BOOK REVIEWS

(Available books may be purchased through the GENERAL ELECTRIC REVIEW for domestic delivery; none sent on approval.)

GIANT BRAINS

Edmund C. Berkeley—John Wiley & Sons, Inc., New York. 1949. xvi+270 pp. \$4.00.

Entitled and styled so as to capitalize on the publicity being given the large-scale computing machinery, this book provides an introduction and a good general coverage of the computer field. It does fill a gap, since little if any information has appeared in book form about calculating machinery.

The author delves into systems for handling information and quickly leads the reader into the design of a simple computing machine, comparing its operations to the thinking processes of remembering, choosing, reasoning, and sorting. In several chapters describing well-known existing machines, Mr. Berkeley points out the importance of these machines to the fields of science, engineering, and accounting and indicates the future of the computing-machinery field.

The book is written in an informal and easily understandable style, such that the reader may follow the main theme or any point deeper into related subjects such as semantics, mathematical logic, and physics. There are also 27 pages of references covering books, articles, and pamphlets on the subjects of machinery for computing and reasoning.

B. R. LESTER

BASIC ELECTRONICS

Royce G. Kloeffler and Maurice W. Horrell—John Wiley & Sons, Inc., New York. 1949. xiv+435 pp. \$5.00.

Basic Electronics has been prepared for a first course in college electronics, to be given to electric-power majors. The authors point out that it is also suitable for electronic or communication majors who will continue with more comprehensive and specialized courses in radio communication, wire communication, ultrahigh frequencies, microwaves, and industrial electronic applications.

In addition to the more conventional topics usually included in a book of this nature, the subjects of transistors and mechanoelectronic transducers have been introduced.

Curves and data for some of the basic tubes have been included so that the reader will be able to work the problems at the end of each chapter without referring to any of the tube handbooks.

This is a well-organized, well-written text which should find wide usage in introductory courses in the subject.

M. D. HORTON

SATURATING CORE DEVICES

Leonard R. Crow—Scientific Book Publishing Co., Vincennes (Ind.). 1949. xiv+373 pp. \$4.95.

The subject of saturating core devices is covered very well here. As outlined in the preface, the book is intended for elementary students of electrical sciences, and therefore many basic concepts are reiterated, establishing a common starting line. Many practical applications and many excellent illustrations provide an interesting background for the theory of saturable reactors. The theory itself is restricted to a ceiling of grasp which can be reasonably expected from elementary students, and the full explanation of some of the more complex

phenomena cannot be expected. Nevertheless, within these boundaries, the explanations are lucid and are well supported by illustrations.

Following what might be called ordinary saturable reactors, nonlinear resonant circuits are described such as are used in regular circuits and for pulsating light control. The addition of a permanent magnet to the laminated structure is discussed, along with its application to a position indicator. Two chapters deal with peaking transformers, of which many forms are shown. Another chapter describes a-c voltage stabilizers. A considerable amount of attention has been given to frequency multipliers, various types of flux-gate compasses, and the application of Magnesyns to servo-mechanisms. This is followed by a chapter on magnetic amplifiers in which many circuits and applications are cited. The last chapter includes the combination of saturable reactors with electronic tubes.

This book is highly recommended for obtaining broad and general information on the subject.

H. F. STORM

PHYSICAL METHODS OF ORGANIC CHEMISTRY: PART I—Technique: Vol. I (2nd Edition).

Edited by Arnold Weissberger—Interscience Publishers, Inc., New York. 1949. xii+1072 pp. \$12.50.

The first edition of this book appeared in 1945 (G.E. REVIEW, Jan. 1946). Its purpose was to provide organic chemists with a description of tested physical methods and the necessary theoretical background for understanding them and evaluating results. The first edition was held in high regard, and since many of the suggestions for its improvement have been adopted, the new edition should be more useful than its predecessor.

This edition contains new chapters on Temperature Measurement, Temperature Control, Determination of Vapor Pressure, and Determinations with the Ultracentrifuge. Several of the original chapters have been completely rewritten, and new sections added. Chapters on X-Ray Diffraction, Electron Diffraction, and Refractometry have been shifted to Part II, which presumably will appear again as a separate volume.

This volume and its companion will probably be used by organic chemists more extensively for the methods of temperature measurement and control, vapor pressure, density, and similar common procedures rather than for the more complex techniques required, for example, with the ultracentrifuge or the precision calorimeter. A most useful feature are the tables at the end of chapters on some of the common methods, which serve to guide the selection of a method in a given instance.

A. E. NEWKIRK

MODERN OSCILLOSCOPES AND THEIR USES

Jacob H. Ruiter, Jr.—Murray Hill Books, Inc., New York. 1949. xviii+326 pp. \$6.00.

The cathode-ray oscilloscope, perhaps the most useful tool in the electronic laboratory today, is truly the eye that allows the engineer to see into and determine what is going on in his complex electronic circuits.

This book will serve as an excellent reference for both the student in the classroom

and the engineer who finds use for the oscilloscope but is not well versed in electronics. It will be especially useful in laboratories where the oscilloscope is used only occasionally.

The pertinent fundamentals of electricity are explained and illustrated in such a manner that the operation of the cathode-ray tube is readily understandable. The author considers, in separate chapters and in good detail, each of the components of the complete oscilloscope. This makes for convenient reference.

A large percentage of the book is devoted exclusively to the application of the oscilloscope to the testing and adjustment of common electronic circuits. Herein is contained an outstanding collection of circuits, suggestions, and ingenious test applications not to be found in any other single book. Included are such devices as radio transmitters and modern television receivers.

With reference to obtaining permanent records from the oscilloscope, the author includes valuable tables and nomographs to assist in selecting the proper camera, photosensitive material, and proper settings of the camera.

The entire book is profusely illustrated with oscillograms which assist in the clear explanation of each point. The pages devoted to Interpretation of Patterns will be found extremely valuable to the occasional user of the oscilloscope. An ample glossary is included to assist the nonelectrical engineer in becoming acquainted with the electronic terminology.

K. R. GEISER

TECHNOLOGY OF LIGHT METALS

Alfred von Zeerleder—Elsevier Publishing Co., Inc., New York. 1949. xiv+366 pp. \$6.00.

This is the English translation of a recent Swiss publication by a recognized European authority on light metals. It covers the more practical aspects of the production, fabrication, and use of both aluminum- and magnesium-base alloys.

The book is descriptive and empirical in approach, dealing in considerable detail with the special techniques and equipment required to process light metals, including the procedures used in the United States and Great Britain as well as those in use on the Continent. A distinct service is rendered by a tabulation of alloy compositions together with their respective trade designations in the several countries. Emphasis is placed upon the necessity of designing specifically for, rather than simple replacement by, light metals. A bibliography of several hundred selected references is included, although they are not annotated in the text.

The language of the book is not difficult, but the style is not pleasant, the translation retaining the long and cumbersome Germanic sentence structure. The few sections on the theory of alloys and plastic deformation leave much to be desired and might better have been omitted.

This book should appeal to a rather limited audience, consisting of those concerned with the practical phases of processing light alloys, who already possess considerable knowledge of current practice in this country and may wish to compare their experience with that of their European counterparts.

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ON ARTICLES IN OTHER TECHNICAL JOURNALS

ALLOYS

EFFECT OF ANNEALING IN A MAGNETIC FIELD UPON IRON-COBALT AND IRON-COBALT-NICKEL ALLOYS PREPARED BY POWDER METALLURGY, by Joseph F. Libsch and others. *Jour. Metals*, Feb., 1950; v. 188, p. 37.

How binary and ternary alloys of iron, nickel, and cobalt respond to annealing in a magnetic field by a characteristic change in the shape of their hysteresis loop.

ELECTRODEPOSITION OF ALLOYS OF PHOSPHORUS WITH NICKEL OR COBALT, by Abner renner and others. *Nat. Bur. Stds. Jour. es.*, Jan. 1950; v. 44, p. 109 (RP No. 2061).

Alloys containing nickel or cobalt and as much as 15 percent of phosphorus have been electrodeposited from solutions containing phosphites.

CALCULATING INSTRUMENTS

STATIC MAGNETIC STORAGE AND DELAY LINE, by An Wang and Way Dong Woo. *Jour. App. Physics*, Jan. 1950; v. 21, p. 49.

Magnetic cores with a rectangular hysteresis loop are used in a storage system which requires no mechanical motion and is permanent.

USE OF THE RELAY DIGITAL COMPUTER, by E. G. Andrews. *Elec. Engng.*, Feb. 1950; v. 9, p. 158.

A description of some of the problems solved successfully by the Bell Laboratories Model V computer.

COIL WINDINGS

REDUCING SETUP TIME ON A COIL WINDER, by William Clark and Carl E. Sullivan, Jr. *Elec. Mfg.*, Feb. 1950; v. 45, p. 86.

Increased production rate and wide range of adjustability with reduced setup time were objectives in developing this new coil winder for short-run work.

WINDING CAPACITANCE, by N. H. Crowhurst. *Electronic Engng.*, Nov. 1949; v. 21, p. 417.

Data sheets and text for computing the various winding capacitances of multi-layer windings in construction of audio-frequency transformers, chokes, and other equipment.

GEARS

INDUCTION-HARDENED GEARS, by H. B. Knowlton and H. F. Kincaid. *Soc. Auto. Engrs. Quar. Trans.*, Jan. 1950; v. 4, p. 16.

Explains methods of handling various gear-hardening jobs and describes production equipment at the International Harvester Co.

PRE-SHAVE GEAR-CUTTING TOOLS, by A. D. Moncrieff. *Tool Engr.*, Feb. 1950; v. 24, p. 26.

States that where gear cutting—whether by hobbing, shaping, or by the shear speed method—is to be followed by gear shaving, it is desirable that pre-shave tools, rather than standard tools, be used if the best results are to be obtained.

TRENDS IN THE DEVELOPMENT OF MARINE REDUCTION GEARING, by A. W. Davis. *Am. Soc. Nav. Engrs. Jour.*, Feb. 1950; v. 62, p. 165.

This article by a member of the Institute of Marine Engineers is reprinted from the Transactions of that Society for 1949.

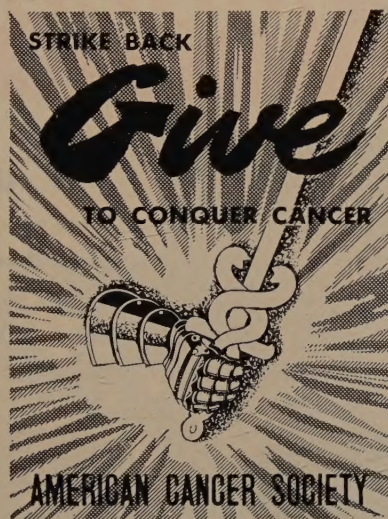
MEASURING INSTRUMENTS

AIRFOIL PITOMETER FOR SIMULTANEOUS MEASUREMENT OF STATIC PRESSURE, VELOCITY, AND FLOW DIRECTION, by Melvin W. First and Leslie Silverman. *Ind. & Engng. Chem.*, Feb. 1950; v. 42, p. 301.

An airfoil pitometer is described and its performance in turbulent and streamlined flow is presented.

VERSATILE PNEUMATIC INSTRUMENT BASED ON CRITICAL FLOW, by W. A. Wildhack. *Rev. of Sci. Instr.*, Jan. 1950; v. 21, p. 25.

A device that can measure temperature and mass flow, that can be a pressure divider or a pneumatic micrometer, or that can analyze gases.



METALS

HOT SPOT MACHINING, by L. T. Friedman. *Iron Age*, Feb. 9, 1950; v. 165, p. 71.

According to this article, microhardness surveys, microstructure examinations, surface analyses, and Faxfilm replicas show that localized heating for machining has no detrimental effects on the hardness, surface condition, and microstructure of finished parts.

HOW TO WORK CLAD MATERIALS, by Wm. M. Stocker, Jr. *Am. Mach.*, Feb. 6, 1950; v. 94, p. 89.

Describes the cladding of metals and their handling, working, finishing, and testing.

STEEL SHOT SPEEDS BLAST CLEANING, SHOT PEENING, by L. J. Wieschhaus. *Iron Age*, Feb. 2, 1950; v. 165, p. 82.

Description of a newly developed cast-steel shot which causes less wear on equipment, lasts longer, and eliminates some pickling.

WHAT YOU SHOULD KNOW ABOUT ELECTROGRAPHIC TESTING. *Steel*, Jan. 23, 1950; v. 126, p. 56.

Recent developments in electrographic methods, valuable for identifying metals, alloys, and inclusions and for testing porosity in organic and metallic coatings.

PIPES AND PIPING

EVALUATION OF DRYSEAL PIPE THREADS, by R. F. Holmes. *Tool Engr.*, Feb. 1950; v. 24, p. 17.

Concerns wide acceptance of American Standard dryseal pipe threads—self-sealing pipe threads developed for refrigeration, marine, and automotive applications.

POWER PIPING PRACTICE—1900-1950, by A. G. Christie. *Heat. Piping & Air Cond.*, Feb. 1950; v. 22, p. 77.

Mentions the use of much higher pressures and temperatures, welded connections, and alloy steels.

PLASTICS

DESIGN THE RIGHT PLASTIC INTO YOUR MAJOR APPLIANCE, by Frank A. Martin. *Elec. Mfg.*, Jan. 1950; v. 45, p. 60.

Practical consideration of selection factors and test control.

PATTERN OF PLASTICS PROGRESS. *Modern Plastics*, Jan. 1950; v. 27, p. 106.

Covers study over a period of 15 years by refrigerator engineers, of plastics and their application to production of better refrigerators at lower cost.

STEEL

DEVELOPMENTS IN THE IRON AND STEEL INDUSTRY DURING 1949, by I. E. Madsen. *Iron & St. Engr.*, Jan. 1950; v. 27, p. 93.

A comprehensive article including electrical developments.

ELECTRICAL DEVELOPMENTS IN 1949, by H. W. Poole. *Blast Fur. & St. Pl.*, Jan. 1950; v. 38, p. 77.

Describes new and improved applications of electricity in the steel industry.

UNIT PROCESSES, CHEMICAL

CHEMICAL ENGINEERING UNIT OPERATIONS. *Ind. & Engng. Chem.*, Jan. 1950; v. 42, p. 13.

The fifth annual review contains sixteen short sections with numerous references.

VIBRATIONS, SUPERSONIC

ULTRASONIC ABSORPTION IN LIQUIDS, by George W. Hazzard. *Acoustical Soc. of Am. Jour.*, Jan. 1950; v. 22, pp. 29-32.

The Debye-Sears methods for measuring ultrasonic absorption is used for various organic liquids at room temperature and at frequencies of 3 to 15 mc per sec.

WELDING

HOW TO MAKE CONSISTENT SPOT WELDS, by J. Heuschkel and H. Bitzer. *Steel*, Feb. 6, 1950; v. 126, p. 82.

Concerns recent studies at research laboratories, indicating that uniformly high-quality welds can be produced successfully by following a well-planned pre-welding control procedure.

WELDABILITY OF METALS BY RESISTANCE WELDING TECHNIQUES, by Wallace A. Stanley. *Prod. Engng.*, Feb. 1950; v. 21, p. 88.

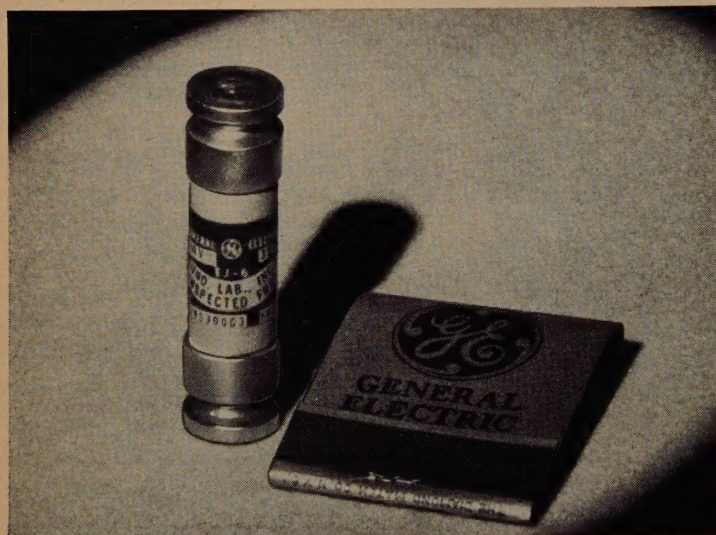
Suitability of metals, alloys, and plated materials for spot, projection, flash, butt, and seam welding. General precautions, and thickness and shape limitations.

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